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Point-of-Use Reduction of Volatile Halogenated Organics in Drinking Water

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POINT-OF-USE REDUCTION OF VOLATILE HALOGENATED ORGANICS IN DRINKING WATER

by

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16. ABSTRACT

Contamination of drinking water by organic chemicals has become a national problem of increasing concern. Small communities faced with the problem of removing these contaminants have limited resources and often cannot afford traditional treatment approaches. One approach which has the potential to be cost effective is treatment at the home, or point-of-use treatment.

This report discusses the results of a study of point-of-use treatment of contaminated ground water in two small communities. Costs for purchase, installation, monitoring, and maintenance are documented and discussed. The effect of the point-of-use treatment on the drinking water quality is presented.

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FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water systems. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. The Clean Water Act, the Safe Drinking Water Act, and the Toxics Substances Control Act are three of the major congressional laws that provide the framework for restoring and maintaining the integrity of our Nation's water, for preserving and enhancing the water we drink, and for protecting the environment from toxic substances. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Water Engineering Research Laboratory is that component of EPA's Research and Development program concerned with preventing, treating, and managing municipal wastewater discharges; establishing practices to control and remove contaminants from drinking water and to prevent its deterioration during storage and distribution; and assessing the nature and controllability of releases of toxic substances to the air, water, and land from manufacturing processes and subsequent product uses. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

Contamination of drinking water by organic chemicals has become a national problem of increasing concern. Small communities faced with the problem of removing these contaminants have limited resources and often cannot afford traditional treatment approaches. One approach which has the potential to be cost effective is treatment at the home, or point-of-use treatment. This report discusses the results of a study of point-of-use treatment of contaminated groundwater in two small communities.

Francis T. Mayo, Director
Water Engineering Research Laboratory

ABSTRACT

A study was conducted to determine whether point-of-use carbon treatment is cost effective for the control of volatile halogenated organic chemicals in small water systems and to study water quality district management techniques for point-of-use treatment. Point-of-use treatment efficacy and costs were monitored in two small communities for the control of eight volatile organic chemicals (VOCs) and four trihalomethanes. The groundwaters in this study were contaminated with one or more of the following VOCs: chloroform, 1,2-dichloroethane, 1,1,1-trichloroethane, 1,1-dichloroethylene, 1,2-dichloropropane, carbon tetrachloride, trichloroethylene, and tetrachloroethylene. The point-of-use treatment method used was granular activated carbon in a line bypass configuration.

Two communities were studied: Silverdale, Pennsylvania, and Rockaway Township, New Jersey. Silverdale has four groundwater wells connected to a community distribution system. Rockaway Township is a collection of homes, served by private wells. Five models of point-of-use devices were selected and installed in approximately 50 homes in Silverdale. Rockaway Township had already selected and installed devices, and was used as a case study.

The devices in Silverdale removed the VOCs from the groundwater for the entire testing period (14 months). Devices in use in Rockaway Township were still removing all VOCs after 24 months.

Breakthrough (detection, in the effluent, of the VOC present in the influent in consecutive samples from the same location) did not occur for any of the devices tested during the 14 months of sampling in Silverdale. However, trace concentrations of VOCs were detected intermittently in postdevice samples for all but one of the models.

Water samples collected in Silverdale had higher microbial densities in post device samples than predevice samples, as measured by standard plate count (SPC). Postdevice microbial densities were affected by the sampling technique used. Samples of water collected after two minutes of flushing had SPC densities comparable to samples of water from the distribution system. If one liter of water was flushed from the line before sampling, postdevice samples had mean densities one order of magnitude higher than predevice samples. Unflushed postdevice samples had mean densities two orders of magnitude higher.

Mean densities of predevice samples collected in Rockaway Township were more than 10 times higher than predevice samples collected in Silverdale. However, Rockaway postdevice microbial densities were not significantly higher than predevice densities. Mean postdevice densities in Silverdale were more than 10 times higher than those in Rockaway.

No evidence existed of coliform colinization on any of the devices in either community. Positive coliform results were intermittently found for postdevice water samples in Silverdale, but follow-up samples were negative for coliform. Fecal coliforms were never found in postdevice samples. A one-time sampling for total Pseudomonas and Pseudomonas aeruginosa in Silverdale was negative.

Postdevice samples from silver impregnated carbon did not have lower SPC densities for devices tested in Silverdale. In fact, mean densities were slightly higher from silver impregnated devices. No comparisons could be made in Rockaway.

The average monthly cost per customer for point-of-use treatment in Silverdale was $5.98, assuming a 20 year capital amortization at 10 percent. The estimated cost in Rockaway Township was $5.06 per customer per month. In both communities, the homeowner is responsible for maintenance. If a water quality district were established to monitor and maintain the devices, the estimated administrative costs (including labor and supplies) would be $1.23 per customer per month for both communities.

This report was submitted in fulfillment of Contract No. R809248010 by the National Sanitation Foundation under the sponsorship of the U. S. Environmental Protection Agency. This report covers the period September 1982 to March 1985.

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The townspeople of Silverdale, Pennsylvania

ENGLISH TO METRIC CONVERSION TABLE

TO CONVERT FROM	TO	MULTIPLY BY
Inches	Centimeters	2.54
Feet	Meters	0.3048
Miles	Kilometers	1.609
Square Miles	Square Kilometers	2.590
Gallons (U.S. liquid)	Liters	3.785
Gallons (U.S. liquid)	Cubic Meters	0.0038
Pounds	Grams	453.6
Pounds/Square Inch	Kilograms/Square Centimeter	0.070
Dollars/Gallon	Dollars/Liter	0.264
Acres	Square Kilometers	0.004

SECTION 1.

INTRODUCTION

BACKGROUND

The presence of chemical contaminants in groundwater has become a potential health threat of national significance. Sources of synthetic organic chemicals are diverse and can be found in rural communities as well as large industrial communities. A private well may even be inadvertently contaminated by its owner through the use of cleaning solvents and other man-made chemicals.

In the Advance Notice of Proposed Rulemaking (ANPRM) for volatile organic chemicals (VOCs), published in the Federal Register on March 4, 1982, 14 compounds were identified as those most commonly detected in drinking water (1). The 14 VOCs are: trichloroethylene, benzene, tetrachloroethylene chlorobenzene, carbon tetrachloride, p-dichlorobenzene, 1,1,1-trichloroethane, trichlorobenzene, 1,2-dichloroethane, 1,1-dichloroethylene, vinyl chloride, cis-1,2-dichloroethylene, dichloromethane, and trans-1,2-dichloroethylene.

In a random sampling of 500 groundwater systems in the United States, approximately 21 percent of the systems contained at least one of the 14 VOCs listed (1). Once contaminated, groundwater supplies may remain so for years or decades (2).

When faced with a groundwater contamination problem, communities and/or individuals must either find new sources of drinking water, or treat the contaminated water. Within those two general approaches, several options may be available. Examples are presented in Table 1.

TABLE 1. OPTIONS AVAILABLE FOR SOLVING GROUNDWATER CONTAMINATION PROBLEMS

Options Involving New Sources	Options Involving Treatment
New well	Central Treatment:
Purchased water	Aeration
Bottled water	Blending
	Carbon adsorption
	Macroreticular resins
	Point-of-Use Treatment:
	Carbon adsorption
	Reverse osmosis (with appropriate membranes)
	Distillation

For large communities, all of these solutions may be feasible; but small communities may not be able to afford new wells or central treatment. The best economic choices for a small community may be bottled water or point-of-use treatment. Point-of-use treatment may include whole house treatment, faucet mounted devices, or under the sink line bypass treatment.

Recommended maximum contaminant levels (RMCLs) were published in the Federal Register for nine of the 14 VOCs listed earlier: p-dichlorobenzene, 1,1,1-trichloroethane, benzene, 1,1-dichloroethylene, vinyl chloride, 1,2-dichloroethane, carbon tetrachloride, tetrachloroethylene, and trichloroethylene. RMCLs are nonenforceable goals for public water systems. They are established based on health effects data only. Before maximum contaminant levels can be established, economics must be determined, including best available technology. The National Primary Drinking Water Regulations state that appropriately designed point-of-use devices that have been shown to be effective for VOC control can also be considered for some small water systems, if they are cost effective and properly managed (3).

In a previous study, various point-of-use carbon treatment devices were tested in the laboratory with spiked municipal water. Some were found to be effective for VOC control (4).

OBJECTIVES

The purpose of this study was to determine whether point-of-use carbon treatment is cost effective for the control of VOCs and to study water quality district management techniques. Point-of-use treatment efficacy and costs were monitored in two small communities for the control of six VOCs and four trihalomethanes (THMs).

In Silverdale, Pennsylvania, the water contamination problem had been identified, but no course of action had been determined. This community provided the opportunity to observe and study point-of-use technology from equipment selection through an extended period of operation. Several point-of-use treatment device models were selected to provide a representative sampling of commercially available products.

In Rockaway Township, New Jersey, the local health department had already initiated a water quality district program to evaluate the feasibility of point-of-use treatment for controlling VOC contamination of private wells. Rockaway Township provided an opportunity to observe a point-of-use strategy already in operation.

SECTION 2.

SUMMARY AND CONCLUSIONS

1. Data from this study indicate that point-of-use granular activated carbon (GAC) treatment devices effectively reduced concentrations of trichloroethylene, tetrachloroethylene, carbon tetrachloride, 1,1,1-trichloroethane, 1,1-dichloroethylene, 1,1-dichloroethane, and chloroform at influent concentrations studied. These results confirm bench and field results from a previous study (4).

2. Breakthrough (defined as consistent detectable concentrations of effluent VOCs) was not observed for point-of-use devices that had been in use for up to 24 months. However, trace concentrations of VOCs were detected intermittently in postdevice samples for all models in place through the entire study.

3. Monitoring (which may include sampling, meter reading, and/or mechanisms for homeowner feedback) should be conducted periodically for water quality districts. For most cases of VOC reduction, it will be more cost effective to replace cartridges prematurely rather than to pay for frequent sampling and analysis. For this method to be used for control of water quality, a relatively consistent raw water quality is required.

4. As with central treatment, maintenance must be provided after installation. Homeowners must be aware of how to request maintenance and monitoring. Some homeowners did not report operational problems immediately.

5. Microorganisms measured by the standard plate count method were present in higher numbers in postdevice water than in predevice water.

6. No evidence of coliform bacteria colonization was found in any of the point-of-use devices.

7. Variation of sampling techniques for microbiological testing of water passing through point-of-use devices will significantly affect the results. If microbiological monitoring of point-of-use devices is planned, sampling methods should be given careful consideration. The methods chosen should be consistently followed.

8. Flushing 1 L of water through the point-of-use device before collecting a sample for microbiological analysis reduced the mean standard plate counts by one order of magnitude over unflushed samples, to a level below 500 organisms per mL.

9. Flushing water through the point-of-use device for two minutes reduced the mean standard plate count by two orders of magnitude over unflushed samples, to a level of less than 100 organisms per mL.

10. The mean standard plate count in treated water from silver impregnated GAC devices was not less than the mean standard plate count from non-silver impregnated devices.

11. Carbon, replacement cartridges, and point-of-use devices should always be stored or packaged in such a way as to minimize possible contamination by solvents. A quality control system should be established by manufacturers and users to help assure contamination has not occurred. Immersing cartridges for 1-2 days in "organic free" water and then analyzing for organic contaminants was effective for detecting methylene chloride contamination in this study.

SECTION 3.

PROCEDURES

STUDY SITE SELECTIONS

Silverdale, Pennsylvania, and Rockaway Township, New Jersey, were selected as study sites for the project. Selection of these sites was based on previous sampling results and interest in both communities in participating in the study.

The primary site for studying point-of-use removal of organic contaminants was Silverdale, Pennsylvania. New point-of-use devices were installed and monitored for a period of 14 months beginning on February 28, 1983. Data collected from this site were used to study the feasibility, costs, performance, and management of point-of-use technology.

Before this project began, the Rockaway Township Department of Health and Welfare had been conducting a study to verify, under actual use conditions, previous U. S. Environmental Protection Agency (EPA) studies concerning GAC point-of-use treatment devices for organics reduction in drinking water. For this project Rockaway Township was used primarily as a case study, although a limited number of samples were collected to verify performance of the devices used. Point-of-use devices at this site had been in use for a year when the project began.

SITE DESCRIPTIONS

Silverdale, Pennsylvania

The Village of Silverdale is located 30 miles north of Philadelphia and lies within the Pleasant Springs Creek Drainage Basin in central Bucks County. The Village has an estimated population of 550, consisting of approximately 200 residences and 15 commercial establishments. Individual septic tanks were used for wastewater treatment within the community until 1981.

Sixty-three homes (about 150 people) in the Village get their water from the W. C. Seidel Water Company. The water company's wells, pumps, and distribution system are privately owned by William and Esther Seidel. The Seidels also serve as part time water system operators. The water source consists of four eight-inch diameter wells with depths of 275, 180, 200, and 150 feet (a table of English to metric conversions is on page xi). All wells are located within a 100 foot radius. Well No. 4 (150 feet) is used as the primary water source. There are two galvanized steel pressure tanks with capacities of 1000 and 3000 gallons. Pressure in the tanks ranges from 60 to

80 psi. Pressure at the farthest point in the distribution system has never been measured at less than 40 psi. Flow through the system is estimated to be 11,000 gallons per day. The only treatment provided is gas chlorination for disinfection.

The primary source of groundwater recharge in the area is local precipitation. Water from the wells is moderately mineralized (334-455 mg/L total dissolved solids), with low levels of iron (0.30-0.43 mg/L) and manganese (0.018-0.036 mg/L). Total organic carbon (TOC) levels in the distribution system average 0.59 mg/L. A summary of water quality in the distribution system and wells is presented in Table 2.

TABLE 2. WATER QUALITY MEASURED IN SAMPLES FROM FOUR WELLS AND THE DISTRIBUTION SYSTEM IN SILVERDALE, PA.

	Mean Concentration				
Analyte	Well 1	Well 2	Well 3	Well 4	Distribution System[1]
Alkalinity (mg/L as $CaCO_3$)	133	122	108	130	131
pH (units)	7.66	7.54	7.56	7.63	7.43
Color (units)	<5	<5	<5	<5	<5
Odor (threshold no.)	1	1	1	1	1
Total Dissolved Solids (mg/L)	384	455	455	334	361
Total Organic Carbon (mg/L)	2.1	2.6	5.0	<0.1	0.59
Turbidity (NTU)	1.0	1.0	4.2	0.6	0.5
Arsenic (mg/L)	0.012	0.005	0.012	0.008	0.008
Barium (mg/L)	0.232	0.282	0.263	0.362	0.309
Cadmium (mg/L)	0.0003	0.0002	0.0002	0.0002	0.0004
Chloride (mg/L)	30	76	86	27	26
Copper (mg/L)	0.002	0.008	0.010	0.006	0.014
Fluoride (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1
Iron (mg/L)	0.30	0.31	0.43	0.31	0.30
Lead (mg/L)	0.002	0.003	0.007	0.003	0.002
Manganese (mg/L)	0.033	0.030	0.027	0.036	0.018
Mercury (mg/L)	0.0002	0.0002	0.0003	0.0004	0.0002
Nitrate-N (mg/L)	0.7	4.1	3.0	1.2	1.2
Selenium (mg/L)	0.002	0.003	0.003	0.003	0.003
Silver (mg/L)	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Sulfate (mg/L)	53	42	36	31	32
MBAS (mg/L)	<0.05	<0.05	<0.05	<0.05	<0.05

[1]Composite of well water collected at a homeowner's faucet which was not connected to the point-of-use device. The contribution of each well to the composite was not known.

In October 1979, the Bucks County Department of Health began routine monitoring of the W. C. Seidel Company's water for VOCs. Initial results showed trichloroethylene (TCE) at 10 µg/L and tetrachloroethylene (PCE) at 2 µg/L. However, within a year, concentrations had reached 65 µg/L for TCE and 12 µg/L

for PCE. The source(s) of the contaminants could not be identified by the Health Department. Septic tank cleaning compounds which had been used in the community until 1981 were suspected. Many of the septic tanks in the community were close to the wells. The length of time the VOCs had been present in the distribution system is unknown.

Silverdale was chosen as a study site because central treatment would be extremely expensive for such a small community and point-of-use treatment seemed feasible. Also, the Seidel Water Company and its customers were willing to participate.

Equipment Selection and Description

Selection of point-of-use devices was based on criteria developed by the Project Advisory Committee. The Committee was composed of both regulatory officials and representatives of the point-of-use industry (see Acknowledgements). Criteria for selection of devices for this study were as follows:

- Greater than 95 percent reduction of halogenated organics demonstrated in the Gulf South Research Institute (GSRI) Phase III study, or equivalent (4). Manufacturers of units not involved in the GSRI study were required to provide validation of testing by an independent laboratory to establish comparable performance. The independent laboratory had to have EPA certification for organics analyses.

- Manufacturers were required to certify that their products will meet the National Sanitation Foundation (NSF) Standard 53, Section 3, concerning structural integrity, corrosion resistance, nontoxicity, etc.

- Point-of-use devices were required to have a rated capacity exceeding 700 gallons (estimated one year service life).

- Point-of-use devices were required to be installable and maintainable by a single contractor. A replaceable treatment cartridge was a desirable feature.

- Point-of-use devices were required to provide on-demand water with no maintenance required by homeowner.

- Manufacturers were required to assure price and availability (up to 15 units within 15 days at a competitive price).

- The community would have the right to select from the list of qualified devices.

- No fewer than eight (preferably 10) of each model selected were to be used in the study. That was the minimum number the committee determined would provide sufficient data for each model. (Forty-seven homeowners participated; consequently the maximum number of models which could be tested was five.)

Information concerning the study objectives and equipment selection criteria was sent to known point-of-use manufacturers by the Water Quality Association and NSF.

Nine manufacturers provided the required product information. Product information was reviewed by NSF. The information for products meeting the selection criteria was summarized and coded. Trade names and manufacturers' names were not identified. This information was given to a committee composed of six citizens of the community. After careful review, the committee listed the coded products in order of preference. The top five were selected for installation. Selection of a total of five models was based on the number of homeowners expressing a desire to participate in the study (47) and the criteria for using a minimum of eight to ten of each model.

For this study, only line bypass models were selected. Descriptive summaries of the models used in Silverdale appear in Table 3.

Rockaway Township, New Jersey

Rockaway Township is located 18 miles northwest of Newark, New Jersey, in the county of Morris. It is 45 square miles in area with an estimated population of 20,000. The study was conducted in the 320 acre Lake Telemark subdivision located in the northern part of the township. The subdivision lies within the Hibernia Brook Drainage Basin and is primarily residential, consisting of approximately 310 private homes and a small commercial district. All homes within the subdivision are served by individual wells. Wastewater is treated onsite with septic tanks.

The geology of the area is characterized by hills of crystalline bedrock composed primarily of granite and gneiss of Precambrian origin. The bedrock, which is fractured and jointed, displays frequent outcroppings and may be covered by up to 15 feet of soil and glacial till (6).

The story of groundwater contamination in Rockaway Township began with the city of Rockaway. In November 1979, high levels of TCE (50-220 µg/L) were detected in two of three wells used to provide water for the 10,000 residents living in the township. This area receives centrally treated water. The two wells were removed from service. The third and largest well remained in use. In October 1980, two ether compounds, di-isopropyl ether and methyl tert-butyl ether, were found at levels sufficient to cause taste and odor problems (70-100 µg/L and 25-40 µg/L, respectively). A water emergency was declared and residents were advised to avoid drinking the water. Nearby unaffected supply systems were identified and residents were advised to obtain drinking water from these sources.

Township officials considered the available treatment options and chose GAC adsorption as the best approach. A GAC adsorption system was purchased for $200,000 (including piping, site work, and a building housing the contactors). The carbon was expected to last six to eight months; however, it was necessary to replace the carbon once every four to six weeks (5).

Subsequent investigations indicated that the length of time between replacement of GAC and breakthrough could be increased significantly by aerating the

water prior to treatment with the carbon. By the end of 1981, a packed column aerator was installed at a cost of $375,000. The combined systems have proven effective, but have increased the costs of potable water from $0.27/1000 gallons before treatment for organics removal to $0.48/1000 gallons after (5). The source of the ether contamination was identified by the township. As a result, most of the installation and operating costs for the system have been borne by the company responsible for contaminating the water.

TABLE 3. DESCRIPTIONS OF POINT-OF-USE DEVICES USED IN SILVERDALE

Device	Description	Estimated Capacity[1] (gallons)	Approximate Volume of Carbon[2] (gallons)	Carbon Wt.[2] (grams)	Estimated Contact Time[3] (seconds)
A	Two PVC cartridges in series containing carbon. Carbon is silver impregnated.	1000	0.18	417	14
C	Single stainless steel cartridge containing carbon.	2000	0.65	1708	78
D	Microfilter and two acetal copolymer cartridges containing carbon. Carbon is silver impregnated.	2000	0.46	1150	19
E	Single stainless steel cartridge containing carbon, compressed into a solid "filter".	1000	0.20	300	6
F	Two cartridges; one with GAC, one with PAC and filterable materials.	2000[4]	0.44	765	62

[1] Estimates for Silverdale water quality based on total weight of carbon and previous performance data (GSRI).

[2] Data from GSRI Phase II Report.

[3] Contact times based on manufacturers' specified maximum flow rate.

[4] Manufacturer only claims 1000 gallon capacity in product literature.

Six to seven months after installation of the central GAC system, organic contaminants were found in water samples from a cluster of private wells located one mile north of the Lake Telemark subdivision. Because citizens were already sensitized to water contamination, the Rockaway Township Health Department became deluged with requests to sample private wells. The health department was legally limited in its involvement in monitoring private wells. It was the homeowner's responsibility to provide proof of contamination before health officials could take action. As a result, homeowners were required to pay for water analysis for the initial sample collected from their wells. A low price of $50 per gas chromatography/mass spectrometry (GC/MS) analysis for any township resident was obtained through competitive bidding. The health department assisted in obtaining the low bid and reviewed and monitored analytical and sampling procedures. Cost to the health department for review and monitoring services was estimated to be $10.00 per sample, including labor, fringes, equipment, and automobile expenses.

Groundwater in the Lake Telemark area originates almost entirely from local precipitation, is relatively unconfined, and moves approximately parallel to the slope of the land (7). Recharging of the aquifer is difficult because of the fractured nature of the underlying bedrock. The groundwater has moderate levels of dissolved solids (312 mg/L), low pH (5.76), low alkalinity (25.6 mg/L as $CaCO_3$), and low concentrations of total organic carbon (0.8 mg/L). (Concentrations reported are averages from four wells.) Wells in the Lake Telemark subdivision range from 50 to 200 feet in depth and have an average yield of six gallons per minute (gpm). A summary of the analysis of water samples from four Lake Telemark wells is presented in Table 4.

Samples from 50 wells in the subdivision were analyzed for organic contaminants; 14 had detectable concentrations of VOCs. The VOCs found included: trichloroethylene, 1,1,1-trichloroethane, 1,2-dichloropropane, 1,1-dichloroethylene, tetrachloroethylene, and 1,1-dichloroethane. Ten wells had VOC concentrations high enough that the township health department recommended the temporary use of bottled water.

A consulting engineering firm was hired by the township in May 1981 to determine the size of the contaminant plume, direction of plume flow, probable contaminant sources, and to estimate the length of time the aquifer would be contaminated (7). Two contaminant plumes were found; both from an undetermined source or sources. It was estimated that the VOCs would remain in the aquifer for 12 years. The report also suggested that, given the slow rate of movement of contaminants in the aquifer, remedial actions be implemented to provide some type of relief to the affected homeowners (7).

A citizens' ad hoc committee was formed to investigate options available for providing potable water to the affected residents. Point-of-use treatment was selected by the committee as the most economical treatment option. The costs of providing homes in this subdivision with centrally treated water was estimated to be $4,000,000, compared to the estimated costs of $60,000 for installing point-of-use devices in all dwellings.

TABLE 4. GROUNDWATER QUALITY MEASURED IN SAMPLES FROM FOUR PRIVATE WELLS IN THE LAKE TELEMARK SUBDIVISION

Analyte	Sample Source			
	Well 1	Well 2	Well 3	Well 4
Alkalinity (mg/L as $CaCO_3$)	25.0	21.3	18.8	37.5
pH (units)	5.97	5.81	5.54	5.72
Color (units)	<10	<10	<10	<10
Odor (threshold no.)	0	0	0	0
Total Dissolved Solids (mg/L)	304	228	422	294
Total Organic Carbon (mg/L)	0.55	0.80	0.40	1.55
Turbidity (NTU)	0.13	0.25	0.49	0.26
Arsenic (mg/L)	<0.002	<0.002	<0.002	<0.002
Barium (mg/L)	0.021	0.020	N/A	N/A
Cadmium (mg/L)	<0.0001	<0.0001	N/A	N/A
Chloride (mg/L)	66	38	140	41
Chromium (mg/L)	<0.0002	<0.0002	N/A	N/A
Copper (mg/L)	0.27	1.72	0.10	S/B
Fluoride (mg/L)	<0.10	<0.10	<0.10	<0.10
Lead (mg/L)	<0.0001	<0.0001	N/A	N/A
Manganese (mg/L)	0.018	0.010	N/A	N/A
Mercury (mg/L)	<0.0002	<0.0002	N/A	N/A
Nitrate-N (mg/L)	2.84	4.16	5.74	6.67
Selenium (mg/L)	<0.001	<0.001	N/A	N/A
Silver (mg/L)	<0.0002	<0.0002	<0.0002	<0.0002
Sulfate (mg/L)	30.0	38.8	27.0	31.6
MBAS (mg/L)	0.029	0.027	0.026	0.036

N/A - Not analyzed based on low concentrations found at first two sites.
S/B - Sample bottle broken in transit to lab.

The committee was then asked to oversee a demonstration project using point-of-use treatment, and began the process of selecting a device which would provide maximum health protection with minimum maintenance. Several types of devices (distillation units, whole-house treatment systems, and line bypass devices) were investigated. Manufacturers' representatives were interviewed and allowed to provide equipment demonstrations.

One point-of-use model was selected for use in 12 homes for demonstrating efficacy. The model used in Rockaway was also selected for the study in Silverdale (Model F).

The township entered into a contract with the manufacturer which included a price reduction and did not require payment until the devices had proven their effectiveness. A provision was also made that homeowners not selected for the demonstration project could purchase devices for the same reduced price (25 homeowners have done so). The manufacturer also agreed to arrange and pay for installation and maintenance, including cartridge replacement, for a period of one year, and to pay 50 percent of the analytical costs incurred to demonstrate efficacy. Monies for sampling costs and the remaining 50 percent of analytical costs were provided by the Rockaway Township Health Department.

Participating homeowners were required to sign documents holding the health department harmless for any negative effects resulting from use of the devices. Installation was completed in October 1981.

At the start of this EPA/NSF study, the devices had been in operation for approximately one year, and were demonstrating greater than 99 percent efficiency in removing VOCs. Average total volume treated per device at this time was estimated to be approximately 800 gallons.

SAMPLING AND ANALYTICAL PROCEDURES

Qualified sample collectors for each study site were selected by NSF staff. Sampling personnel were provided with written sampling and preservation instructions, and with required sampling containers for the analyses to be performed. Sampling techniques were reviewed onsite to ensure proper sampling. Sample types collected were grab samples of predevice and postdevice water in both communities. Grab samples were also collected directly from the supply wells in Silverdale.

Volatile Organic Chemicals

Sampling, sample preservation, and analytical procedures for VOCs were in accordance with Federal Register, 44, No. 231, Part II, November 29, 1979, and Federal Register, 44, No. 233, Part III, December 3, 1979, as amended. Specific analytical methods used were: liquid/liquid extraction (EPA Method 501.2), purge and trap (EPA Method 601), and gas chromatography/mass spectrometry (EPA Method 624). Use of these methods allowed qualitative and quantitative determination of a broad spectrum of VOCs.

Samplers were instructed to let water run for 1 to 2 minutes before collecting a VOC sample. For predevice samples, this assured samples were representative of water in the distribution system. Postdevice samples collected from flowing taps assured that the water sampled represented the minimum water/carbon contact time.

All VOC samples were collected in duplicate. A field blank accompanied every sample batch. VOC samples were shipped in freezer packs to NSF for analysis.

Although sampling procedures were in accordance with prescribed techniques (11), 17 percent (134 samples) of the 788 samples collected had a small headspace when they reached NSF. The headspace volumes were estimated to be zero to 1.0 mL. Samples were collected in duplicate, and one of a pair was usually free of headspace.

A study of the effect of headspace and holding time was conducted to determine if sample headspace and headspace combined with holding time would cause significant loss of VOC.

A description of the study and results is presented in Appendix A. The results indicated that significnt loss of VOC did not occur for up to 0.5 mLs of headspace. Data from samples with apparent headspace greater than 0.5 mLs were not used in this report.

EPA Method 501.2 for liquid/liquid extraction is used primarily for determination of trihalomethanes in finished drinking water, drinking water during the treatment process, and raw source water. The technique is not restricted to trihalomethanes, however, as it efficiently extracts a broad range of non-polar organics, and also certain polar organics, with varying efficiencies. The technique involves extraction of the sample using pentane, and injection of a portion of the extracted pentane into a gas chromatograph equipped with a linearized electron capture detector. A 30 mL aliquot of sample was extracted instead of the normal 10 mL volume. This modification improved detection, precision, and accuracy.

EPA Method 601 uses a variation of the Bellar purge and trap technique for measurement of 29 purgeable halocarbons, including the trihalomethanes, trichloroethylene, tetrachloroethylene, 1,1,1-trichloroethane, 1,2-dichloroethylene, 1,1-dichloroethane, and carbon tetrachloride. The method is used to measure specific compounds which are expected to be present in the water to be analyzed. The technique requires injection of a sample into a specially designed purging chamber through which an inert gas is bubbled. Halocarbons contained in the generated vapor are trapped in a sorbent tube, which is then heated and backflushed to desorb the compounds into a gas chromatograph.

Gas chromatography/mass spectrometry (GC/MS) (EPA Method 624) is applicable to the determination of the same VOCs which can be detected by the purge and trap method. For this study, GC/MS was used as a screening mechanism to confirm the presence of the compounds detected by the liquid/liquid extraction and purge and trap methods. This technique is essentially the same as the purge and trap technique with the addition of a mass spectrometer, which provides both qualitative and quantitative information.

The Quality Assurance plan was administered in accordance with the NSF Quality Assurance Manual, NSF, Ann Arbor, Michigan, 1983, and the NSF Chemistry Laboratory Quality Control Manual, NSF, Ann Arbor, Michigan, 1983. Routine analytical quality control included: duplicate analyses of all samples; analysis of field blanks with each batch of samples; spikes, controls and standards with each analytical series; and periodic anlaysis of EPA QC check and performance standards. A detailed quality control data package was submitted to the EPA. A summary of precision and accuracy results for VOCs using liquid/liquid extraction is presented in Table 5.

TABLE 5. PRECISION AND ACCURACY OF VOC ANALYSES USING LIQUID/LIQUID EXTRACTION

Analyte	Percent Relative Precision	Percent Accuracy
1,1,1-Trichloroethane	8 ± 5	93 ± 6
Tetrachloroethylene	8 ± 5	98 ± 6
Trichloroethylene	2 ± 1	99 ± 5
Chloroform	5 ± 5	93 ± 4
Bromoform	4 ± 4	95 ± 6
Bromodichloromethane	9 ± 6	95 ± 8
Chlorodibromomethane	13 ± 13	99 ± 5

Laboratories in New Jersey and Pennsylvania were selected to perform analyses for which holding times did not allow sample transport to NSF. Subcontract laboratories had current EPA certifications for the analyses they performed.

Microbiological

Samples analyzed for standard plate count and total coliform content were collected using several different sampling techniques. Techniques included the standard method of collecting water samples for microbiological analysis, i.e., from disinfected taps which were flushed for two to three minutes. The two minute flush provides water which is representative of water in the distribution system. This technique was used for samples collected from August 1983 through April 1984. Samples were also collected from unflushed, undisinfected taps (March 1983-February 1984), and from undisinfected taps after a one liter flush (March 1984-April 1984). The latter techniques were efforts to collect samples representative of water in the pipe between the carbon bed and the end of the tap, and of water in the carbon bed itself. These procedures were used for both predevice and postdevice samples.

In Silverdale, all samples were collected in the morning. Homeowners were notified in advance of the dates for which their homes would be sampled. They were asked not to use the device on the morning of sampling until after the samples were collected. Samples for microbiological analysis were always collected before VOC samples.

Preparation of sample containers, sample preservation and transportation, and analysis of samples were performed as outlined in Microbiological Methods for Monitoring the Environment, Water and Wastes, USEPA-600/8-78-017, December 1978. The following sampling modification was made:

- Chambers neutralizing solution (5 percent sodium thiosulfate, 7.3 percent sodium thioglycolate) was added to samples collected from devices containing silver impregnated carbon (1 mL neutralizer to 100 mL sample).

General Water Quality Analysis

Sampling, preservation and analytical procedures used for all other analytes were in accordance with Methods for Chemical Analysis of Water and Wastes, USEPA-600/4-79-020, March 1979.

Cost Data Collection

Reported costs for point-of-use GAC treatment in Silverdale and Rockaway were based on either direct experiences during the study, community records, or if specific costs were unavailable, on the assumptions presented in the text.

SECTION 4.

RESULTS

VOLATILE ORGANIC CHEMICAL REDUCTION

Predicting Breakthrough

All devices used in this study used activated carbon as the adsorption media. The carbon adsorption process is particularly amenable to the removal of organics from water. Certain specific organic contaminants may be more effectively or more cheaply removed by other processes, but activated carbon is the best process for reduction of a broad spectrum of organics (8).

When designing a carbon adsorption system for removal of organic chemicals from water for a specific treatment goal, factors which affect the efficiency of the adsorption process can be optimized. Manufacturers of point-of-use devices do not have the same opportunity to design for a specific water treatment goal. Point-of-use devices are designed with many important variations; quantity of carbon, type of carbon, internal flow patterns, number of cartridges, etc. All of these variables can affect performance. Point-of-use treatment devices are generally designed to provide effective treatment for a variety of water qualities. Looking at any one factor and trying to predict performance for a specific water treatment problem or device may be misleading.

Once a device is installed, however, the adsorption principles which affect the removal of organics will not change. Consequently, consistent performance may be anticipated. A knowledge of these adsorption principles, coupled with performance information for a specific device, may be used to predict breakthrough behavior and establish an effective monitoring plan.

The following discussion briefly focuses on the basic principles of carbon adsorption. An example is presented of how those principles might be applied to predict the order of breakthrough for a mixture of VOCs using one type of carbon.

Carbon is a good adsorbent because it provides a large surface area per unit volume. Although there are areas of localized charge on the carbon surface, the adsorption mechanism is "physical" as opposed to electrostatic for exchange sorption. The energy for physical adsorption is predominantly provided for by van der Waals forces. The relatively weak adsorption energy allows molecules to adsorb and desorb, moving along the carbon surface. One molecule may also be displaced by a molecule having stronger carbon affinity.

Adsorption of an organic molecule from water onto carbon is the result of two properties of the solvent-water-carbon system. The first property is the tendency of a molecule to leave solution (hydrophobicity). The tendency to leave solution can be indicated by the solubility of the molecule. That is, the less soluble the molecule, the less likely it will stay in solution. Larger molecules may exhibit both hydrophilic and hydrophobic properties, with functional groups and/or branches of one molecule exhibiting contrasting solubility properties (9).

The second property is the affinity of the molecule for the carbon surface. This affinity is the result of a number of properties of the molecule and the carbon surface. Molecular size and structure will influence the energy of adsorption between the molecule and the surface and the rate of diffusion of the molecule within the internal pore structure. The surface characteristics of the carbon will also influence the energy of adsorption. Molecular affinity for carbon can be demonstrated empirically with isotherms. Isotherms represent the quantity of solute adsorbed onto the carbon surface as a function of solute concentration in water.

The properties affecting adsorption can be assessed collectively using empirical solubility and isotherm data. Isotherm and solubility data for the VOCs of interest in this study are presented in Table 6 (10). Column one shows the concentration of granular activated carbon (mg/L) required for a 100 µg/L reduction in the VOCs listed. This magnitude of reduction fits the range of VOC concentrations found in this study. The solubilities of the VOCs are presented in column two.

TABLE 6. RELATIVE CARBON AFFINITY FOR VOCs AND VOC SOLUBILITY IN WATER

VOC	Required Carbon Dose (mg/L)[1]	Solubility (mg/L @ 25°C)
Methylene chloride	1,100	20,000
Chloroform	210	8,200
1,2-Dichloroethane	190	8,300
1,1-Dichloroethane	120	5,000
1,1,1-Trichloroethane	90	4,400
1,1-Dichloroethylene	70	5,000
1,2-Dichloropropane	68	2,700
Carbon tetrachloride	61	795
Trichloroethylene	15	1,000
Tetrachloroethylene	7.1	200

[1] Computed from Freundlich isotherm data for Filtrasorb 300 as the quantity of carbon in a column adsorber required for a 100 µg/L reduction of contaminant at neutral pH (10).

The VOCs are listed in increasing order of adsorbability, with methylene chloride least adsorbable and tetrachloroethylene most adsorbable. That order would also be the same order for which breakthrough would likely occur.

Therefore, if methylene chloride and tetrachloroethylene were co-contaminants, methylene chloride would be found in device effluent before tetrachloroethylene.

The correlations between solubility and isotherm data are good for these compounds. One might surmise from both sets of data that breakthrough would occur in the order presented. The use of these data as a predictive tool could theoretically reduce analytical costs for a point-of-use monitoring program. Analysis for only the least adsorbable chemical in the device effluent would reduce analytical costs.

Silverdale, Pennsylvania

Table 7 presents a summary of VOCs found in Silverdale water samples during the study. Mean results of VOC analyses of well water and predevice samples are presented.

Well water samples were collected prior to chlorination. Predevice samples were collected at kitchen cold water taps. Predevice sample results reflect the quality of the influent water after some residence time in the distribution system.

TCE and PCE were the contaminants most consistently measured at relatively high concentrations in predevice samples during the study (approximately 80 and 20 µg/L, respectively). Chloroform and carbon tetrachloride were also consistently found in predevice samples, but at concentrations generally less than 10 µg/L.

TABLE 7. SUMMARY OF INFLUENT VOC RESULTS, SILVERDALE, PENNSYLVANIA (MARCH 1983 - APRIL 1984)

Compound	Mean Concentrations (µg/L)[1]				
	Well 1	Well 2	Well 3	Well 4	Predevice
Trichloroethylene	36.2	12.0	22.0	83.8	80.4
Tetrachloroethylene	7.5	3.5	5.0	19.7	20.6
1,1,1-Trichloroethane	1.1	<1.0	<1.0	1.4	1.1
1,2-Dichloroethane	<1.0	<1.0	<1.0	<1.0	<1.0
Carbon Tetrachloride	1.4	<1.0	1.1	7.0	8.0
Chloroform	1.6	1.0	4.3	5.5	6.7
Bromodichloromethane	1.0	<1.0	3.4	1.2	1.5
Dibromochloromethane	1.4	<1.0	2.6	<1.0	1.4
Bromoform	1.2	<1.0	<1.0	<1.0	<1.0

[1] Samples with <1.0 µg/L of a VOC were assigned a value of 0.9 µg/L for calculation of the mean.

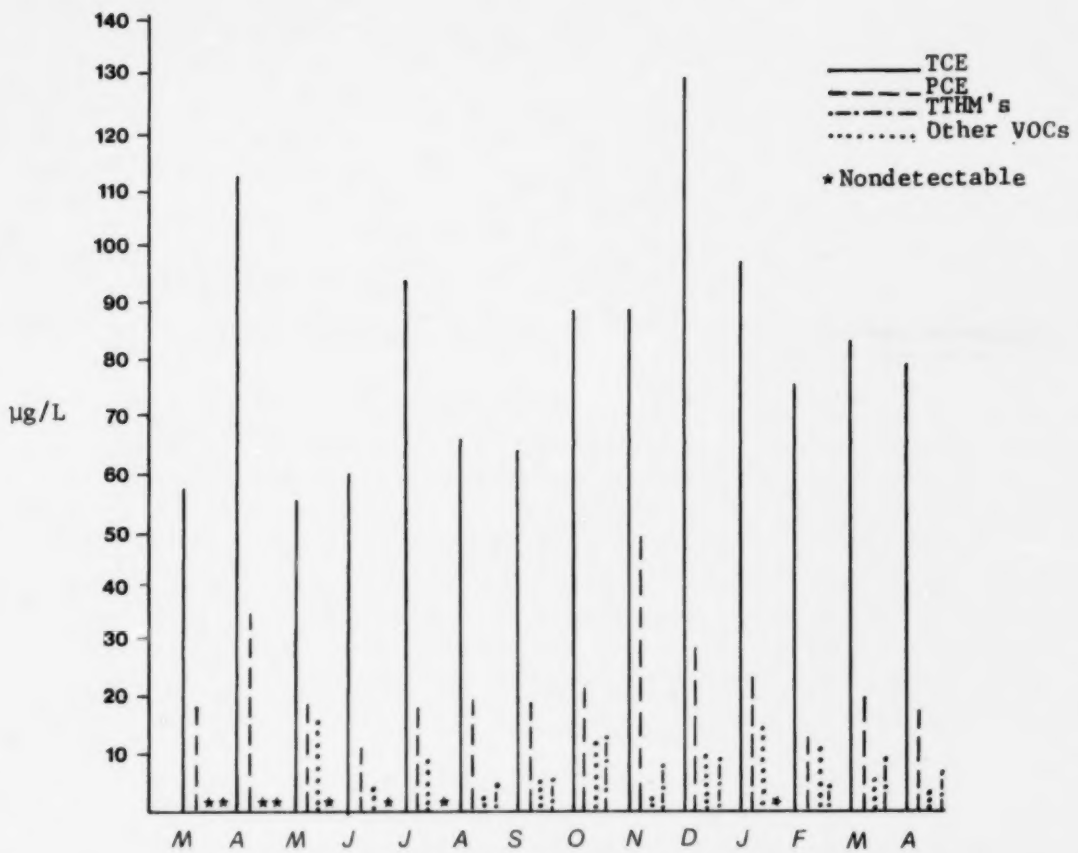

Figure 1. Mean VOC concentrations in influent samples collected by month.

Figure 1 shows the mean influent VOC concentrations in distribution system (predevice) samples. The results are presented by month for TCE, PCE, TTHMs, and the other VOCs found (1,1,1-trichloroethane and carbon tetrachloride). The concentrations of VOCs found varied from sample to sample. For example, the range of results for TCE was 133 µg/L with a relative standard deviation of ± 31 percent. Predevice samples were collected at different locations in the distribution system during the study, but there was no apparent pattern in VOC concentrations which could be attributed to sampling location. There also does not appear to be a seasonal pattern to VOC concentrations.

Figure 1 does seem to show an increase in influent TCE concentration during the study. In fact, the mean TCE concentration from March 1983 through September 1983 was 69.4 µg/L. From October 1983 through April 1984 the mean TCE concentration was 80.9 µg/L, an average increase of 31 percent. The mean PCE concentrations for the same two time intervals were 19.5 µg/L and 21.7 µg/L, an 11 percent increase. The VOC concentrations in Silverdale groundwater are not decreasing.

The influent VOC concentrations closely paralleled the concentrations found in Well No. 4. Well No. 4 was used as the primary water source for Silverdale.

The four wells are close together and of similar depths (see site descriptions). The local health department indicated that VOC concentrations in the well water appear to increase with use rate (13). Consequently, regardless of which well is selected as the primary source, influent VOC concentrations will not vary significantly.

Postdevice samples were collected from each home a minimum of one time every two months during the 14 month sampling period. Each location was sampled at least seven times during the study. Additional samples were collected when VOCs were detected to verify the result. Therefore, some locations were sampled more than seven times.

For this study, breakthrough was defined as detection of the same VOC in consecutive postdevice samples from the same location at a concentration above the routine detection limit of 1.0 µg/L. Breakthrough did not occur for any of the devices tested during the 14 months of sampling for TCE and PCE. However, trace concentrations of VOCs were detected intermittently in postdevice samples for all models which were in place during the entire study. The VOC data are presented in Appendix B.

Overall, the reduction of VOCs achieved by the five models of point-of-use devices was good. Table 8 presents the mean and maximum VOC concentrations for postdevice samples for the time interval March 1983 through November 1983. Data are presented only through November of 1983, because Model A was removed from service in November. Table 9 presents mean and maximum VOC concentrations for the entire sampling interval, March 1983 through April 1984, for the four models in service during the entire sampling interval.

In addition to the mean and maximum VOC concentrations, the number of samples in which VOCs were detected versus the number of samples analyzed is also presented. Of 332 postdevice samples collected during the study, 41 had at

least 1 VOC present. The most frequently measured VOC was TTHMs (chloroform), which was detected 32 times. The number of times detected for other VOCs was: carbon tetrachloride, 16; TCE, 15; 1,1,1-trichloroethane, 13; and PCE, 7.

TCE and PCE were detected at concentrations exceeding the routine detection limit of 1 µg/L in two consecutive samples at two locations but, these occurrences were not considered to be caused by breakthrough. One location used Model C. A potential for physical bypass for this model was discovered because of cartridges which did not match manufacturers size specifications. All Model C cartridges were replaced with properly sized cartridges, and additional TCE and PCE breakthrough did not occur. The other location used Model E. A third sample at this location had non-detectable concentrations of TCE and PCE, but the cartridge was replaced to assure that breakthrough and/or bypass would not occur.

Model D had two occurrences of TTHMs (specifically chloroform) detected in consecutive samples above the routine detection limit of 1.0 µg/L. These were the last two samples collected for the study at both locations. The consecutive concentrations measured were 1.6 and 5.0 µg/L, and 1.4 and 1.1 µg/L, concentrations well below the EPA maximum contaminant level of 100 µg/L. Although the mean concentration of chloroform reported in Table 7 is 12 times less than the TCE concentration, chloroform may be breaking thorugh first. This would support the predicted breakthrough order discussed earlier. This is also supported by the fact that chloroform was always detected in samples which had TCE and PCE, but not all samples which had chloroform had TCE and PCE.

Although the overall VOC reduction performance for Model E was good, there was a higher frequency of detection of trace concentrations of VOCs in Model E effluent than the other models. However, there was no pattern in the detection of VOCs which could be related to volume of water treated. It was discovered late in the study that the carbon in some of the cartridges for Model E had become contaminated with methylene chloride after they were manufactured. The presence of an organic contaminant on the surface of the carbon would affect the adsorption properties and performance of the carbon. This may be why the Model E effluent results were less consistent than for other models, and why VOCs were detected more frequently in Model E effluent.

The right hand column in Tables 8 and 9 presents a summary of the volume of water treated at each location at the time the last VOC sample was collected. Cartridges for Model C were replaced during the fifth month, so the mean and maximum flows are lower than the other models. Model A was replaced by Model E during the ninth month of sampling, so the final mean volume for Model E is lower than for Models D and F. Based on the mean volumes treated for Models D and F, the average daily flow through the point-of-use devices was one gallon.

TABLE 8. POSTDEVICE VOC CONCENTRATIONS BY MODEL AND VOLUME TREATED, SILVERDALE, PENNSYLVANIA (MARCH 1983 - NOVEMBER 1983)

Mean[1] and Maximum Concentrations (µg/L), and Number of Samples with Detectable Concentrations

	TCE	PCE	1,1,1-Trichloroethane	TTHMs	Carbon Tetrachloride	Volume Treated (gal)[2]
Model A						
Mean	<1.0	<1.0	<1.0	<1.0	<1.0	216
Maximum	<1.0	<1.0	<1.0	<1.0	<1.0	<400
No. detected/total[3]	0/33	0/33	0/18	0/19	0/15	
Model C						
Mean	2.0[4]	<1.0	<1.0	<1.0	<1.0	102
Maximum	19.0	<1.0	<1.0	2.0	<1.0	227
No. detected/total	2/33	2/33	0/20	3/22	0	
Model D						
Mean	<1.0	<1.0	<1.0	<1.0	<1.0	344
Maximum	<1.0	<1.0	<1.0	<1.0	<1.0	831
No/ detected/total	0/36	0/36	0/20	0/23	0/17	
Model E						
Mean	25	1.1	<1.0	<1.0	1.2	343
Maximum	22.2	4.5	<1.0	1.4	4.7	638
No. detected/total	5/36	3/36	0/21	1/20	3/14	
Model F						
Mean	<1.0	<1.0	<1.0	<1.0	<1.0	250
Maximum	<1.0	<1.0	<1.0	<1.0	<1.0	603
No. detected/total	0/35	0/35	0/24	0/23	0/16	

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[1] Samples with <1.0 µg/L of a VOC were assigned a value of 0.9 µg/L for calculation of the mean.

[2] Volume of water treated at the time the last sample was collected for each model.

[3] The number of times a VOC was detected versus the number of samples analyzed.

[4] 31 of 33 samples <1.0 µg/l. Mechanical problem with one cartridge produced 2 high samples.

TABLE 9. POSTDEVICE VOC CONCENTRATIONS BY MODEL AND VOLUME TREATED SILVERDALE, PENNSYLVANIA (MARCH 1983 - APRIL 1984)[1]

	Mean[2] and Maximum Concentrations (µg/L)					
	TCE	PCE	1,1,1-Trichloroethane	TTHMs	Carbon Tetrachloride	Volume Treated (gal)[3]
Model C[4]						
Mean	<1.0	<1.0	<1.0	1.1	<1.0	235
Maximum	1.0	<1.0	1.2	4.2	<1.0	394
No. detected/total[5]	3/59	2/59	2/46	8/46	2/40	
Model D						
Mean	<1.0	<1.0	<1.0	1.0	<1.0	516
Maximum	<1.0	<1.0	1.2	5.0	<1.0	1,126
No. detected/total	2/68	0/68	5/56	7/56	5/49	
Model E[6]						
Mean	1.9	1.1	<1.0	1.2	<1.0	287
Maximum	24.3	7.4	1.6	19.8	4.7	730
No. detected/total	9/104	5/104	5/89	11/89	7/83	
Model F						
Mean	<1.0	<1.0	<1.0	1.0	<1.0	328
Maximum	2.9	<1.0	1.6	6.6	<1.0	721
No. detected/total	1/68	0/68	1/56	6/56	2/49	

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1 Model A was replaced in November and is not included in this table.

2 Samples with <1.0 µg/L were assigned a value of 0.9 µg/L for calculation of the mean.

3 Volume of water treated at the time the last sample was collected for each model.

4 Carbon cartridges for Model C were replaced in August because of mechanical problems. Data for Model C are for August 1983 - April 1984.

5 The number of times a VOC was detected versus the number of samples analyzed.

6 Model E cartridges were replaced in May 1984.

Rockaway Township, New Jersey

Twelve point-of-use treatment devices were installed on private wells in the Lake Telemark area of Rockaway Township, New Jersey, on October 22 and 23, 1981. Samples of the well water were anlayzed for VOC concentrations a week before installation. The results of those analyses are summarized in Table 10.

TABLE 10. VOCs IDENTIFIED IN TWELVE PRIVATE WELLS IN ROCKAWAY TOWNSHIP[1]

VOC	Range of Concentrations Found (µg/L)	Number of Wells With VOCs
1,1,1-Trichloroethane	1.0 - 240.0	8
1,1-Dichloroethylene	6.7 - 20.7	4
Tetrachloroethylene	1.0 - 12.3	7
1,1-Dichloroethane	<0.4 - 10.1	6
Trichloroethylene	0.7 - 240.2	4
trans-1,2-Dichloroethylene	0.8 - 5.1	2
Chloroform	1.7 - 2.1	2
Trichlorofluoromethane	<25.0	1

[1]Results of samples collected October 14, 1981; courtesy of Rockaway Township Health Department.

The predominant organic contaminants were 1,1,1-trichloroethane, 1,1-dichloroethylene, 1,1-dichloroethane, trichloroethylene, and tetrachloroethylene. These contaminants and their respective concentrations varied considerably from site to site. The individual wells used for water supply probably tapped different aquifiers. It is also believed that there is more than one source for these contaminants in the area.

After the twelve devices were installed, the local helath department supervised the sampling and analysis of water treated by the devices from October 1981 until October 1982. The health department reported 100 percent reduction of all VOCs through the first twelve months.

In September 1982, samples were split between the commercial laboratory which had been providing analyses for Rockaway Township, the National Sanitation Foundation, and a referee laboratory selected by NSF. The results of the round robin sampling are presented in Table 11. These are results of samples from four wells. Only results of VOCs reported at more than trace concentrations are shown. The agreement between the three laboratories was good.

The Rockaway Township Health Department continued limited sampling from October 1982 through October 1983. Four of the twelve locations were scheduled for sampling. Table 12 presents results for those four sites. Sites 1, 2, and 3 were sampled in October 1982 and July and October of 1983.

TABLE 11. RESULTS OF ROUND ROBIN ANALYSIS OF PAIRED VOC SAMPLES FROM ROCKAWAY TOWNSHIP (µg/L) (Paired Nondetectable Results Not Reported)

VOC	NSF[1]	Laboratory RTS[2]	SRL[3]
1,1,1-Trichloroethane	220	162	230
	58	41	70
Trichloroethylene	70	87	60
	160	204	170
1,1-Dichloroethane	8.8	8.6	10
	3.6	2.7	<10
1,1-Dichloroethylene	7.2	3.7	<10
	2.0	0.6	<10

[1]National Sanitation Foundation

[2]Rockaway Township subcontract laboratory

[3]Subcontract referee laboratory

TABLE 12. VOC CONCENTRATIONS AT FOUR POINT-OF-USE TREATMENT SITES IN ROCKAWAY TOWNSHIP (µg/L) October 1982 - October 1983

	1,1,1-Trichloroethane	Trichloroethylene	Tetrachloroethylene
Site 1			
Predevice Mean	155	<1	2
Predevice Range	82-230	<1 - <1	<1 - 3
Postdevice Mean	<1	<1	<1
Postdevice Range	<1 - <1	<1 - <1	<1 - <1
Site 2			
Predevice Mean	29	1.3	1
Predevice Range	10 - 57	<1 - 2	<1 - 2
Postdevice Mean	<1	<1	<1
Postdevice Range	<1 - <1	<1 - <1	<1 - <1
Site 3			
Predevice Mean	<1	94	<1
Predevice Range	<1 - <1	52 - 161	<1 - 1
Postdevice Mean	<1	2	1
Postdevice Range	<1 - <1	<1 - 4	<1 - 2
Site 4			
Predevice Mean	6	155	<1
Predevice Range	<1 - 12	150 - 160	<1 - <1
Postdevice Mean	<1	<1	<1
Postdevice Range	<1 - <1	<1 - <1	<1 - <1

Four additional sites were also sampled in October 1983, the 24th month of operation. There were no VOCs measured in postdevice samples at 8 sites after 24 months of operation in Rockaway Township. VOC data for Rockaway Township are in Appendix C. Flowmeters were not installed on devices in Rockaway Township.

The average use rate in Rockaway was estimated at 2.2 gpd, based on several readings taken from a total flow indicator on the device. After two years of service, average total flow was approximately 1650 gallons. Efficacy data demonstrate that the devices used were effective in removing VOCs at the concentrations encountered after two years of service. Only one of the 21 postdevice samples collected yielded detectable levels of any VOC (4 µg/L TCE and 2 µg/L PCE). One device was sampled after reaching its estimated treatment capacity of 2000 gallons and still produced water with non-detectable VOCs.

As with most groundwater supplies, the Rockaway predevice TOC concentrations were low. This low total organic loading could improve the capacity of carbon.

MICROBIOLOGICAL GROWTH IN POINT-OF-USE DEVICES

Silverdale, Pennsylvania

Bacteriological quality of predevice and postdevice water was monitored at all installations in Silverdale using Standard Plate Counts (SPC) and coliform isolation. No attempt was made to measure or identify specific microbial species in water from the carbon beds.

Three different sampling methods were used during the study to collect water samples for microbiological testing. One method was the standard technique of faucet disinfection and flushing the line for at least two minutes prior to collecting the sample. The purpose of this method is to sample water in the central distribution system and which has not been stagnant in the plumbing, and possibly contaminated by growth on faucets or other plumbing appurtenances. The second method was to collect an unflushed sample from an undisinfected faucet, or the first water out of the faucet. This technique simulated water which would be consumed if the faucet were not allowed to run before a glass of water was drawn. The third technique was to flush one liter of water from the line prior to collecting the sample from an undisinfected tap. This method was used to discard the water in the plumbing between the carbon bed and the faucet. Partial flushing would more closely reflect the bacterial density in the first flush of water through the carbon bed. It would also represent water from a faucet allowed to run a few seconds.

Efforts were made in Silverdale to collect the first flow of water through a device on its sampling day. Homeowners were notified of the days on which samples would be collected at their home. They were asked not to use their device until after the samples were collected. Sample collection usually was started by 6:00 a.m. and completed by noon. SPC data by sampling location are presented in Appendix B.

Table 13 shows the geometric mean, median, and range of paired samples collected using the three sampling techniques. A one liter flush reduces the mean postdevice standard plate count and brings the bacterial density down to a level less than 500 organisms per mL, a level often cited as a possible standard for SPC. Continued flushing reduces the level another order of magnitude, but does not completely eliminate the microorganisms.

TABLE 13. BACTERIOLOGICAL SAMPLING METHOD COMPARISON, RESULTS OF PAIRED SAMPLES, SILVERDALE POSTDEVICE STANDARD PLATE COUNTS (#/mL)

Sampling Method	Number Samples	Geometric Mean	Median	Range
Unflushed, Undisinfected Tap	143	1630	2300	2-5800
Flushed, Disinfected Tap	143	24	16	1-4200
Partial Flush (1 L), Undisinfected Tap	33	220	330	1-5800
Flushed, Disinfected Tap	33	13	6	1-1500

One liter flush samples were collected for the final two months in place of unflushed samples. The total number of one liter flush samples was not large; therefore, most of the discussion of microbial growth will involve unflushed samples.

Table 14 summarizes microbial results recorded for all samples collected from unflushed faucets in Silverdale, the primary sampling technique used for the study. Mean SPC results from postdevice samples (1380 organisms/mL) were significantly higher than those from predevice samples (4 organisms/mL), indicating microbial colonization of the carbon bed. This is an established effect of treating water with GAC and has been documented in a number of studies (14, 15, 16). Background organisms were present in nontreated (predevice) faucet water in spite of the maintenance of a mean chlorine residual of 0.5 mg/L in the distribution system.

TABLE 14. STANDARD PLATE COUNT SUMMARY FOR UNFLUSHED SAMPLES, SILVERDALE (MARCH 1983 - APRIL 1984)

		Standard Plate Count (#/mL)		
Location	Number Samples	Geometric Mean	Median	Range
Predevice	187	4	6	1-1300
Postdevice	297	1380	3700	1->5800

Monthly means for unflushed plate counts in predevice and postdevice water are shown in Figure 2. During the last two months (March and April, 1984), samples were collected after a partial flush. All remaining samples were from unflushed faucets. Postdevice plate counts increased during the warmer months (May-October), then returned to previous levels as temperatures decreased.

Mean and median values and ranges of postdevice standard plate counts for each model used in Silverdale are presented in Table 15. Data are presented for flushed and unflushed samples for the time period February through November, 1983. After November, Model A was replaced, and direct comparisons are not possible. Geometric means of SPC densities in unflushed samples were all reasonably close for the five models; however, median values showed a larger spread, 1600 to 3250 organisms per mL.

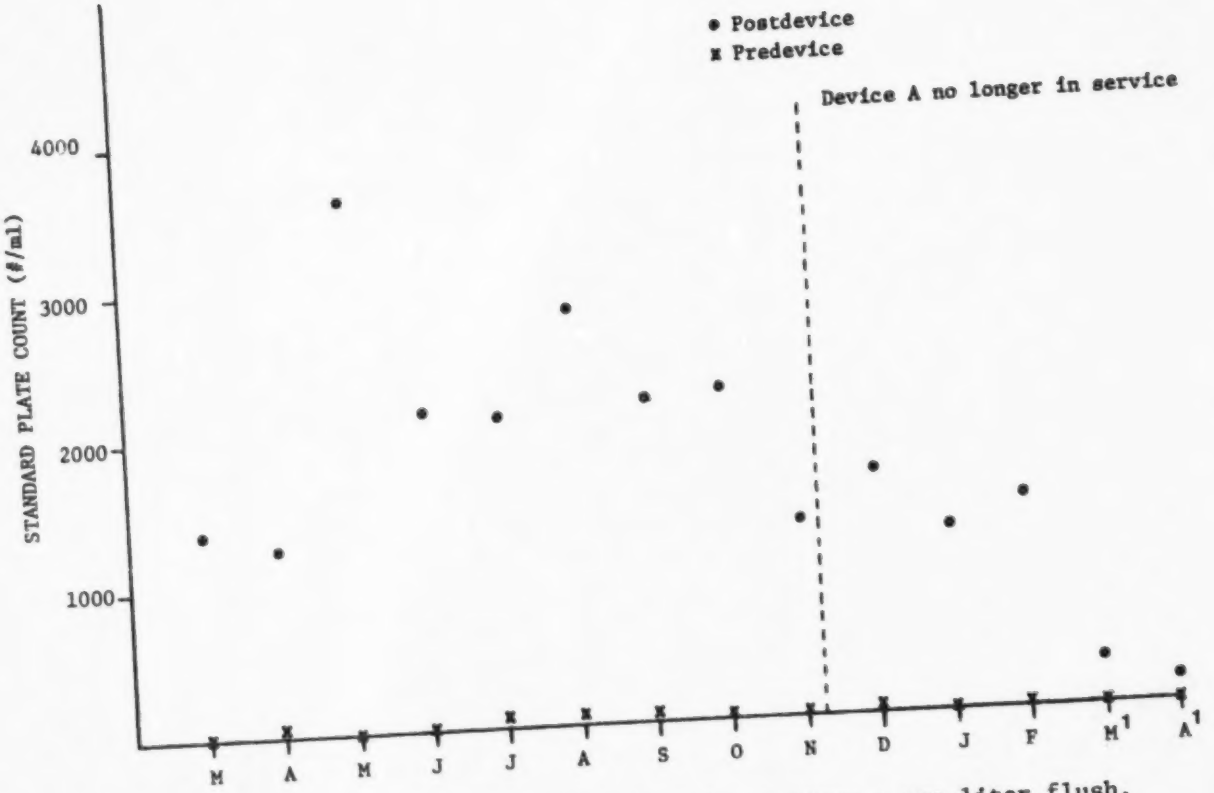
The flushed sample results are quite different. There is no consistent pattern to the differences which can be easily related to model design or quantity of carbon used. Models C and D do use more carbon than A and E, but not significantly more than Model F.

TABLE 15. POSTDEVICE STANDARD PLATE COUNT RESULTS FOR FLUSHED AND UNFLUSHED SAMPLES BY MODEL TYPE[1]

	Standard Plate Count (#/mL)		
Model	Geometric Mean	Median	Range
A Unflushed	1672	2900	35->5800
Flushed	16	3	1-2300
C Unflushed	1528	1600	39-5800
Flushed	51	50	3-1300
D Unflushed	2252	2700	180-5800
Flushed	556	560	130-4200
E Unflushed	1515	3250	1-5800
Flushed	12	9	1-280
F Unflushed	2186	2700	6-5800
Flushed	6	9	1-110

[1]For the period February through November 1983. Not all samples were paired.

Table 16 shows median SPC densities for each model, as well as grams of carbon and whether or not the carbon is silver impregnated. Under the conditions encountered in this study, silver impregnation does not appear to affect microbial density. Combined mean and median SPC densities for silver and non-silver impregnated carbon are presented in Table 17. There is not a significant difference in the microbial densities; however, the SPC densities in postdevice samples from silver impregnated carbon devices are higher.



[1]Samples collected from an undisinfected tap after a one liter flush.

Figure 2. Geometric means of Silverdale pre and postdevice standard plate counts by month.

All of these observations relate to the samples collected in Silverdale. Microbial populations may vary significantly with changes in chemical quality of the water supply.

TABLE 16. MEDIAN POSTDEVICE STANDARD PLATE COUNTS BY MODEL AND CARBON WEIGHT (Unflushed Samples Only)

Model	Weight of Carbon (gms)	Silver Impregnated	Median Postdevice SPC (#/mL)
A	417	Yes	2900
C	1700	No	1600
D	1150	Yes	2700
E	300	No	3250
F	765	No	2700

TABLE 17. POSTDEVICE STANDARD PLATE COUNTS FOR MODELS WITH AND WITHOUT SILVER IMPREGNATED CARBON (Unflushed Samples Only)

	Standard Plate Count (#/mL)		
	Geometric Mean	Median	Range
With Silver	1960	2800	35->5800
Without Silver	1740	2500	1-5800

Median SPC densities for unflushed samples versus grams of carbon are presented in Figure 3. The data correlate well, with a slope of -1.008 and a correlation coefficient of 0.933.

The correlation of median SPC densities with grams of carbon is an empirical observation. All five models have different design features which could affect the postdevice SPC densities. Although efforts were made to control sampling by collecting the first flow of water through a device on its sampling day, it could not always be verified. To adequately study any correlation between SPC densities and carbon quantity would require an experiment designed for the purpose. If, in fact, postdevice bacterial densities could be reduced by using more carbon, then that could be a good design parameter for point-of-use treatment devices. However, further study is needed.

Standard Plate Counts are typically performed using Tryptone Glucose Yeast Agar, most often referred to as Standard Methods Agar (SMA), and a 48 hour incubation period at 35°C. It has been reported that some bacteria frequently found in potable water will not grow on this media (17). As a result, a media used to enumerate bacteria in natural oligotrophic water (R2A) was adapted for use in potable water. The populations enumerated by R2A media with SMA media were compared by parallel testing with the two media. Unflushed postdevice samples were collected once a day, five days a week for a 30 day period. Samples were collected from four devices (two silver and 2 non-silver), split, and plated on SMA and R2A media. Plates were incubated at 35°C and were counted at 48 and 72 hours. A summary of the results appears in Appendix D.

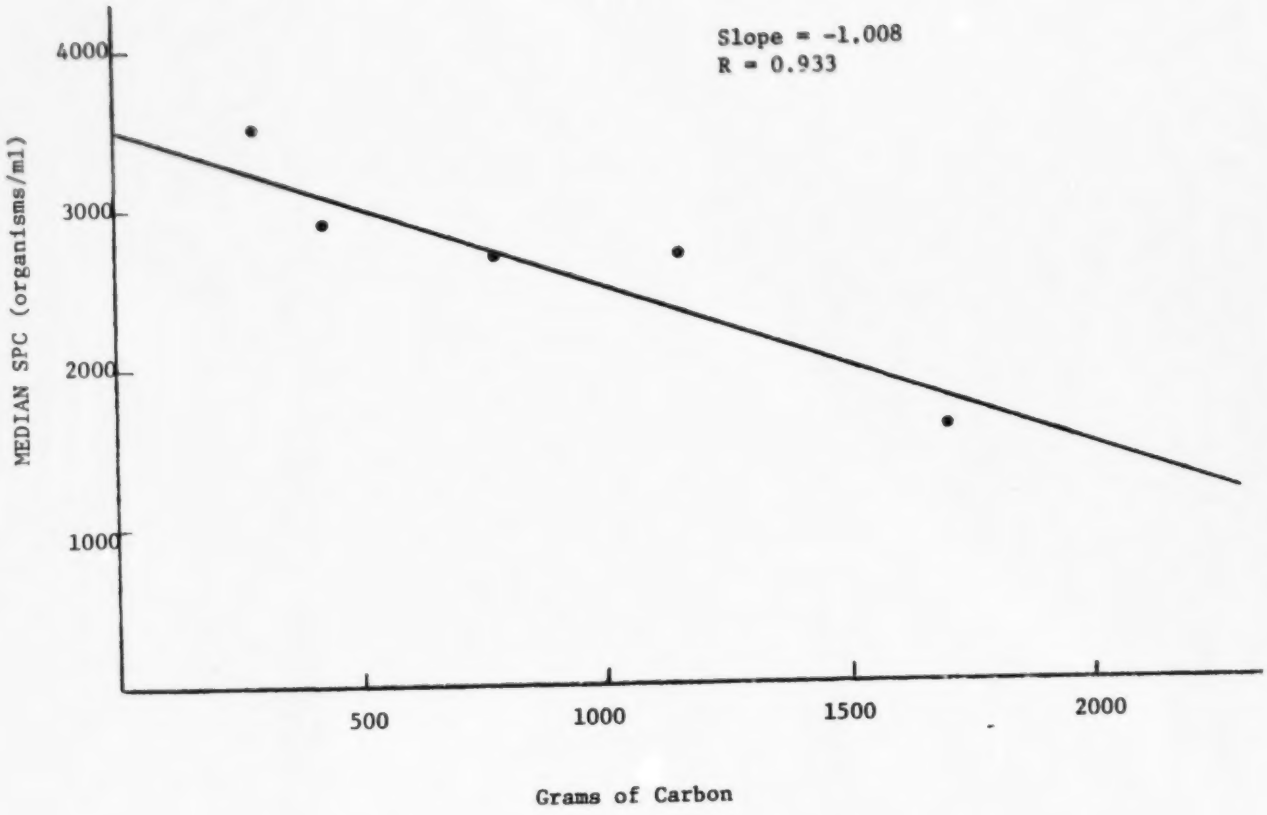


Figure 3. Median postdevice SPC densities versus grams of carbon.

A comparison of R2A and SMA is shown in Figure 4. The R2A and SMA media yielded comparable results indicating that SPC organisms sampled during the study were predominantly oligotrophic. This would be expected for groundwater like Silverdale's, with low nutrient and substrate concentrations. Positive coliform results were obtained from 27 of 297 postdevice samples collected from unflushed, undisinfected taps, and from 4 of 176 postdevice samples collected from flushed, disinfected taps. Resamples collected at the four sites yielding positive results were collected from flushed, disinfected taps. Resamples tested negative for coliform organisms. The occurrence of coliforms could not be correlated with standard plate count densities. The data collected in Silverdale do not indicate that coliform bacteria colonize GAC devices. It is possible that coliform contamination of the water is occurring after passing through the carbon.

Several investigators have identified organisms in carbon beds and in effluent water (19, 20). The most frequently reported genus is Pseudomonas. Efforts were made to isolate this genus in January 1983 when eight postdevice samples, two from each model, were collected from unflushed, undisinfected taps. Samples were analyzed for total Pseudomonas and Pseudomonas aeruginosa. No organisms of this genus were detected.

Rockaway Township, New Jersey

Standard Plate Counts and coliform analysis were performed on predevice and postdevice water samples collected at ten sites in Rockaway. Table 18 presents a summary of SPC data collected from unflushed, undisinfected taps. Mean plate counts were higher in postdevice samples than in predevice samples. Although the difference is significant (tested at 95 percent confidence level using student "t" distribution), it is not as pronounced as that found in Silverdale. The mean postdevice SPC was an order of magnitude lower than that reported for Silverdale. This is somewhat of a surprise, as chlorination is not practiced on private wells in Rockaway, and the predevice SPC mean is two orders of magnitude greater than that observed in Silverdale. Several possible explanations exist for this, including microbial floras composed of organisms sufficiently different in their ability to colonize the carbon or compete for nutrients, or inhibition or injury to the organisms present caused by exposure to chemical constituents found in the water or in material concentrated by the carbon. It is also interesting that the point-of-use devices used in Rockaway contained silver impregnated carbon. Silver may be more effective on the organisms native to Rockaway, but comparable data for non-silvered models in Rockaway are not available.

Fourteen postdevice samples were collected from both unflushed, undisinfected taps and from flushed, disinfected taps and analyzed by SPC. Data are summarized in Table 19. Postdevice samples collected from flushed, disinfected taps had microbial densities one order of magnitude lower than unflushed samples.

No coliform organisms were detected in any postdevice samples collected in Rockaway.

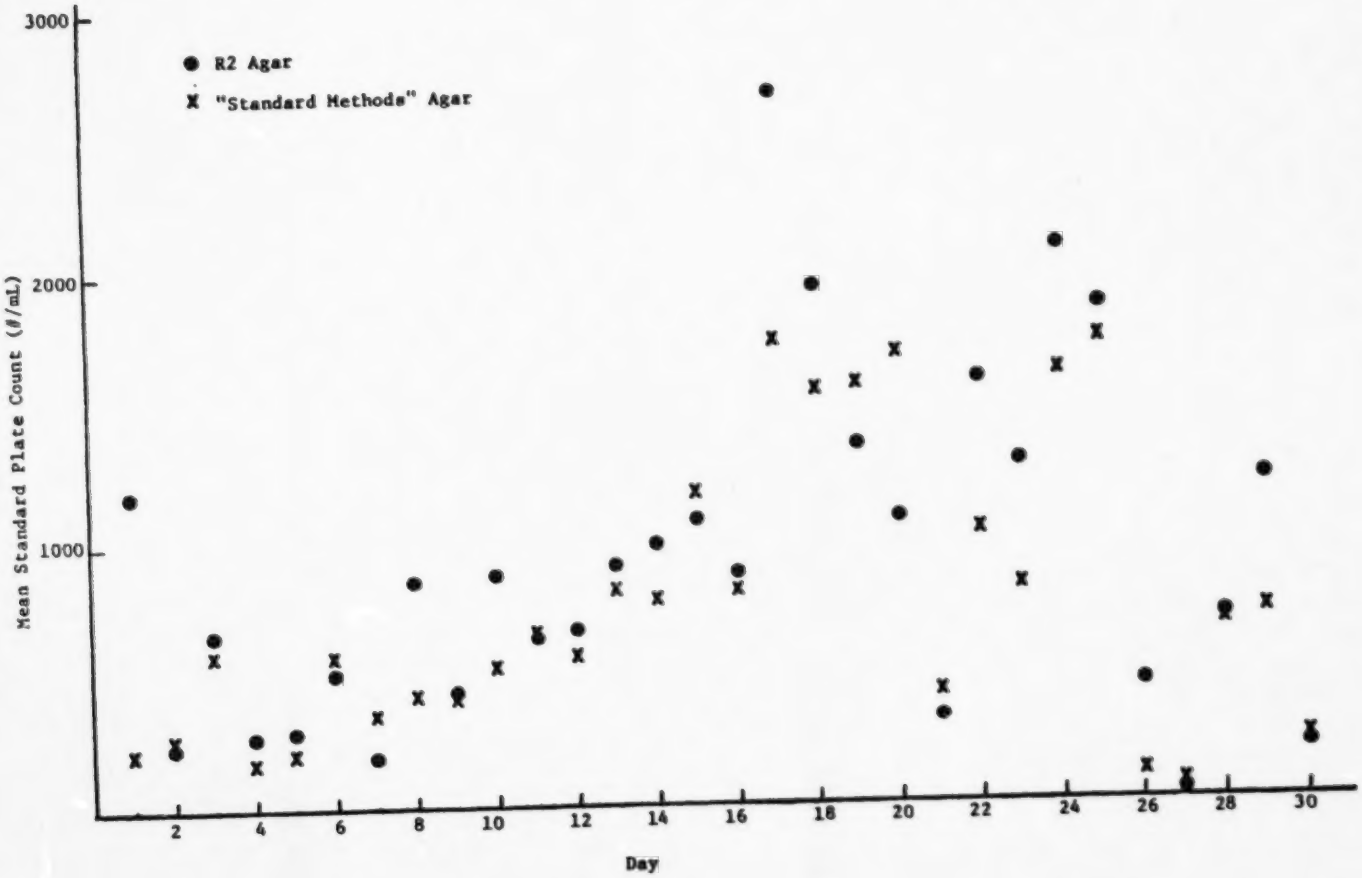


Figure 4. Comparison of standard plate count agar, unflushed postdevice samples, March-April, 1984.

TABLE 18. ROCKAWAY STANDARD PLATE COUNT DATA SUMMARY (Paired Samples Only)

Location	Number Samples	Standard Plate Count (#/mL) Geometric Mean	Median	Range
Predevice	23	130	155	40-54,000
Postdevice	23	210	160	40-32,000

TABLE 19. ROCKAWAY SPC DATA COMPARING SAMPLING TECHNIQUES (Paired Samples Only)

Technique	Number Samples	Standard Plate Count (#/mL) Geometric Mean	Median	Range
Unflushed/Undisinfected	14	250	350	<10-3,2000
Flushed/Disinfected	14	35	<10	<10-3600

COSTS

Silverdale, Pennsylvania

Equipment Purchase and Installation

Table 20 shows a detailed cost breakdown for the purchase and installation of the five models installed in Silverdale. Costs for system components reflect manufacturers' discounted retail prices for purchases in lots of ten or more for January 1983. Data are presented in terms of a basic GAC line bypass unit with sink mounted taps. The system includes the housing and cartridge(s), tap, water meter[1], and all connective fittings. The Seidel Water Company was subcontracted at $20.00/hour to perform installation and maintenance.

Installation of 47 devices was completed in an 18 day period. An additional two devices were requested at a later date and installed within six days. Installation of the devices, taps, and water meters took from 1.5 to 3.25 hours per household, depending on the model, type of sink, and installation problems encountered. The 3.25 hour installation time was probably longer than most similar devices because of problems with improperly sized parts for one model. Average times for installation of the various models, neglecting problems caused by improperly sized parts, ranged from 1.5 to 2.0 hours, with an overall average time for all models of 1.7 hours.

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[1]Water meters are not required by the manufacturer, but are important for monitoring device life and performance.

TABLE 20. CAPITAL COSTS FOR POINT-OF-USE DEVICES USED IN SILVERDALE

Item Cost	Model A	Model C	Model D	Model E	Model F	Average Cost
Device and Tap[1]	$ 227	$ 170	$ 225	$ 232	$ 192	$ 209
Water Meter	38	38	38	38	38	38
Connective Fittings	5	22	5	5	5	8
Total Equipment Costs	270	230	268	275	235	256
Installation ($20/hr)	34	40	32	30	31	33
Total Capital Costs	304	270	300	305	266	289

[1] Device and tap costs include point-of-use device, sink mounted tap and shipping costs, based on a purchase of 10 or more units.

The average capital cost of a GAC installation in Silverdale was $289. Differences in total capital costs for the five models are not very large, with costs ranging from $266 to $305. Installation costs were fairly consistent. If citizens paid for capital cost and installation over a 20 year service life, amortization of the average capital cost at ten percent for 20 years would cost $2.83 per customer, per month.

Operation and Maintenance

Average repair costs incurred over one year of service for the devices used in Silverdale ranged from $1.00 to $35.00 per installation. The average annual repair cost for the 49 devices was $17.14 per unit or $1.43 per device per month. Repair costs are based only on labor costs of $20.00 per hour. All materials needed for repairs were provided by the manufacturers free of charge.

Repairs performed on devices in Silverdale were more frequent than expected.

The overall maintenance frequency was biased to the high side by the number of different models used. All models used in Silverdale required some attention by maintenance personnel. Problems encountered included leaking, intermittent flow through the device, and contaminated carbon.

Three of the five models used in the study had some leaking problems. For one model, glued joints of the PVC housing leaked in six of ten installations. Leaks developed over an eight month period. The manufacturer reported that leaking was the result of production quality control problems and replaced several of the devices in the first month of the study. Subsequent leaking in one of the replacements and in several of the original devices eventually led to the replacement of this model. The replacement model was one in use in Silverdale at the time, and was selected by the Seidel Water Company based on low maintenance requirements. Thus, at the conclusion of the study the community had only four different models.

A second model had intermittent leaks at tubing-cartridge connections. Leaks developed on at least one occasion in all devices of this model installed in Silverdale. Connective fittings were replaced by the manufacturer's representatives, but this was only a temporary solution; several devices continued to develop leaks. Leaking caused damages in two homes of $250 and $300. Damages were covered by the manufacturer's liability insurance, but reimbursement took several months. The cause of the leaks was eventually determined. The manufacturer replaced all units in service. No further leakage occurred. GAC cartridges from the devices which were replaced were installed in the new device to provide cartridge continuity for the study.

A single unit of a third model developed a small leak immediately after installation. A return visit by maintenance personnel revealed the leak had stopped without intervention. No further maintenance was required.

Several homeowners reported that the devices in their homes would not always provide water on demand. Investigation revealed that all these devices were of one GAC model, and that the intermittent flow was common to all the devices of that model installed in Silverdale. Discussions with the manufacturer resulted in identifying the problem as slightly oversized carbon cartridges. The oversized dimensions were attrituted to supplier error and led to the replacement of the cartridges. This corrected the problem, and no further reports of intermittant flow were received.

Operational problems observed with another model used in Silverdale were rather surprising. Samples collected from some installations of this device contained methylene chloride at levels up to 316 µg/L. Investigation into VOC sample collection, handling, and storage showed no source of this contamination. Repeated sampling, however, continued to reveal methylene chloride at high concentrations in postdevice water, while predevice water collected at the same locations showed no detectable levels. Subsequent investigation revealed that a methylene chloride spill had occurred in a storage area at the manufacturer's warehouse, and methylene chloride was adsorbed by nearby GAC cartridges. The cartridges in use were replaced with new cartridges in May 1984.

Before the replacement cartridges were used five were selected at random for a brief immersion test to determine whether or not they were contaminated. The cartridges were unpacked, and placed in organic free water (Milli-Q) contained in a jar which was sealed with no headspace. Exposure times of up to 144 hours showed methylene chloride at a minimal background level. When contaminated cartridges were tested this way, high concentrations of methylene chloride were found. The remainder of the new GAC cartridges were then used to replace those in use. Replacements were installed in May 1984, and did not affect VOC removal data.

Anticipated routine cartridge replacement frequencies in Silverdale were estimated using each manufacturer's rated capacity to predict replacement costs. An average measured water use rate of 1.0 gpd was used. Replacement frequency estimates ranged from 2 to 5 years. Yearly replacement was assumed for particulate prefilters. Replacement costs for each model were multiplied by the number in service and divided by the estimated years of service. The sum of the cartridge replacement costs per year was divided by 49 (total devices in

Silverdale). This gave an average replacement cost of $20.61 per year per device, or $1.72 per month per device. Model specific costs ranged from $0.48 to $3.11 per month. GAC cartridge replacement costs are based on the manufacturer's discounted retail prices for single purchases for January 1983.

Average monthly customer costs are summarized in Table 21. The average total monthly customer cost for a point-of-use device in Silverdale was $5.98.

TABLE 21. ESTIMATED AVERAGE MONTHLY CUSTOMER COSTS - SILVERDALE, PA

Capital Cost (GAC equipment, connective fittings, and installation labor)[1]	$2.83
Operation Cost (Including maintenance labor)	1.43
Replacement Cartridge Cost	1.72
Total customer cost	$5.98

[1] Amortized at 10% for 20 years

Rockaway Township

Equipment Purchase and Installation

Equipment for point-of-use GAC treatment in Rockaway Township did not include a water meter. The model was equipped with a shutoff flow meter. An average installation cost of $30.00 (1.5 hours labor) was assumed based on installation costs for the same model in Silverdale. Total capital costs for Rockaway Township, including GAC equipment, connective fittings, and installation labor, were $255 per installation. The capital cost of $225 for equipment in Rockaway was negotiated by the community.

Operation and Maintenance

In Rockaway, GAC cartridge life was assumed to be 2.4 years based on the manufacturer's rated treatment capacity of 2000 gallons and an estimated use rate of 2.3 gallons per day. The use rate was estimated by flow shutoff readings taken at the time of postdevice sample collection. Total estimated replacement costs were $1.77 per month per device based on these assumptions.

No maintenance was reported during the two year demonstration period.

Average monthly costs including cartridge replacement and maintenance labor are presented in Table 22. Average monthly customer costs are estimated to be $4.23.

TABLE 22. ESTIMATED AVERAGE MONTHLY CUSTOMER COSTS - ROCKAWAY TOWNSHIP, NJ

Capital Cost (GAC equipment, connective fittings, and installation labor)[1]	$2.46
Cartridge Replacement Cost[2]	1.77
Total Customer Cost	$4.23

[1] Amortized at 10% for 20 years

[2] No maintenance costs were reported during the two year demonstration period.

Monitoring Costs

Costs for sampling and microbiological analyses were $20 per sample in Silverdale. The same laboratory provided VOC analyses on request at $50 per sample. These costs will vary depending on laboratory capability, proximity, and whether sampling is subcontracted or provided by the community. The Silverdale costs are typical of fees charged by commercial laboratories.

An additional variable which affects monitoring costs is the sampling frequency chosen by the community. Unlike relatively inexpensive inorganic analyses, VOC analyses generally will cost more than replacement cartridges. Consequently, it could be more cost effective to replace cartridges before they become exhausted than to try to fully use cartridge capacity by closely monitoring for breakthrough.

It is recommended that communities selecting point-of-use treatment conduct a pilot study by operating a device on the community water supply at continuous flow until breakthrough occurs. This pilot study will establish the device's capacity for the quality of water, and could be completed in less than three days for most devices. Raw water quality should be monitored during normal operation to assure that the quality has not changed and that the pilot study results are still valid.

Water Quality District Administration Costs

The costs presented thus far would be costs incurred by homeowners, regardless of whether they particpated in a water quality district program or not. For private homeowners, the only costs that would differ would be capital amortization, and discounts provided by quantity purchases. Private homeowners could decrease one time capital and installation costs through normal private financing routes.

If a community chooses to establish a water quality district, routine administrative costs will be incurred. These administrative costs could include record keeping, billing, and parts inventory control.

Thunderbird Farms, Arizona has had a water quality district (for fluoride removal) established for over four years (21). Their records indicate that 200 hours per month are required to maintain 1500 records for a total of 643 customers (some customers have more than one record). That amounts to 0.133 hours per month per record. Assuming a district would operate on a quarterly billing basis, 0.40 hours per quarter per record is required for maintenance. Assuming $8.00 per hour (including fringe) for record keeping, the cost per customer is $3.20 per quarter.

Telephone, postage, and miscellaneous supplies for the 643 customers are $1,275 per year, or $0.495 per quarter, or $0.17 per customer per month.

Therefore, total administrative costs are $3.70 per quarter, or $1.23 per month. Labor rates may vary. Costs could be reduced through voluntary labor and/or more active homeowner participation.

SECTION 5.

CURRENT MANAGEMENT STATUS

SILVERDALE, PENNSYLVANIA

All point-of-use devices installed in Silverdale were still in service as of August 1984 (18 months). Participating homeowners were notified of their responsibility for service and for the associated costs of any maintenance and cartridge replacements. Homeowners were provided with conservative estimates of projected cartridge life and the meter readings at which the current carbon cartridges should be replaced. Addresses and phone numbers of both local distributors and manufacturers' headquarters, along with quoted prices for replacement cartridges, were also provided.

By replacing cartridges at a conservatively estimated volume treated, expensive sampling and monitoring will not be necessary, provided the concentration of contaminants in the raw water does not change significantly. Monitoring requirements may change if the VOCs become regulated under the Safe Drinking Water Act.

ROCKAWAY TOWNSHIP, NEW JERSEY

The field verification study of point-of-use efficacy conducted in Rockaway Township is completed. Under the formal agreement between the township and the manufacturer, participants in the study now have the option to either purchase the devices at a reduced rate or have them removed at the manufacturer's expense. Should the homeowners choose to keep them, they will have responsibility for maintenance and carbon cartridge replacement. It is assumed that those individuals wishing to keep the devices will make arrangements for service with the manufacturer. The township cannot require a private well owner to install a point-of-use device.

The Rockaway Township Department of Health and Welfare is in the process of developing recommendations for using GAC point-of-use treatment based on the results of the verification study. These are to include conditions for use (not all VOCs are effectively removed by GAC), lists of products considered to qualify for use (models used in the GSRI study or from manufacturers providing the results of an independent evaluation), and monitoring considerations. Health officials prefer models with automatic shut-off valves but will not require that automatic shutoffs be part of a GAC installation. Monitoring recommendations will most likely include VOC and bacteriological sampling and analysis on an annual basis. Health officials are also considering picking up the cost of annual VOC sampling of those devices treating water from the most contaminated wells (22).

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APPENDIX A

EFFECTS OF HEADSPACE AND HOLDING TIME ON VOC RECOVERY

Effect of Sample Headspace and Holding Time on VOC Analytical Results

Most of the samples collected for VOC analysis were shipped to the NSF Laboratory in Ann Arbor, Michigan for analysis. Although sampling and shipping procedures were in accordance with prescribed techniques, 17 percent (134 samples) of the 788 samples collected had a small but perceptible headspace when they arrived at the lab. The volume of the headspace ranged from zero to 1.0 mL.

Samples were collected in duplicate, so at least one of the pair usually was free of headspace. However, a study of the impact of headspace and holding time was conducted to determine what effect sample headspace, and headspace combined with holding time, might have on analytical results.

Tetrachloroethylene (PCE), trichloroethylene (TCE), and 1,1,1-trichloroethane were selected as study chemicals because they were the primary chemicals of interest in both Rockaway and Silverdale. Spike concentrations of approximately 20 µg/L, 50 µg/L, and 50 µg/L, respectively, were added to Milli-Q water (pH 5.3) individually and as a mixture of all three.

Forty mL glass vials were filled to overflowing with the spiked water. A teflon septum was placed on the vial. The septum was removed and a volume of water was removed from the vial. The volumes removed were 1.0 mL, 0.5 mL, 0.25 mL, and 0.0 mL. The septa were replaced, and the vials capped and sealed. Vials were stored at 4°C for 1 hour, 1 day, 3 days, 7 days, 10 days, and 14 days. Duplicate vials for each headspace volume and time period were analyzed. The study was repeated one time, making a total of 384 analyses.

Mean percent recoveries were calculated based on the original sample concentrations listed in Table A-1. Figure A-1 shows mean percent recoveries versus headspace volume for each chemical from vials spiked with one chemical. Figure A-2 shows percent recovery versus headspace for vials containing all three chemicals (multiple spike). Figures A-3 and A-4 show single and multiple spike recoveries versus holding time. The dotted lines indicate 100 $\pm$ 10 percent recovery.

It is apparent that as headspace volume increases, there was some decrease in percent recovery. With the exception of the single spike for PCE, recoveries remained within the $\pm$ 10 percent range for headspaces of up to 0.75 mL. In all cases, percent recovery remained within a range of 100 $\pm$ 10 percent for up to 0.5 mLs of headspace.

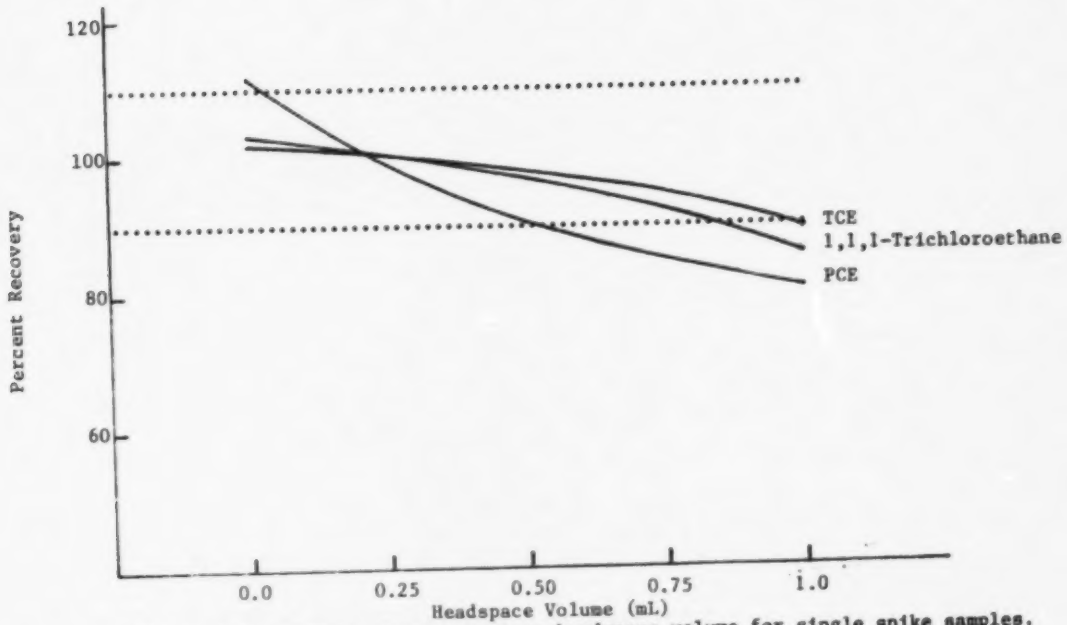

Figure A-1. Percent recovery versus headspace volume for single spike samples.

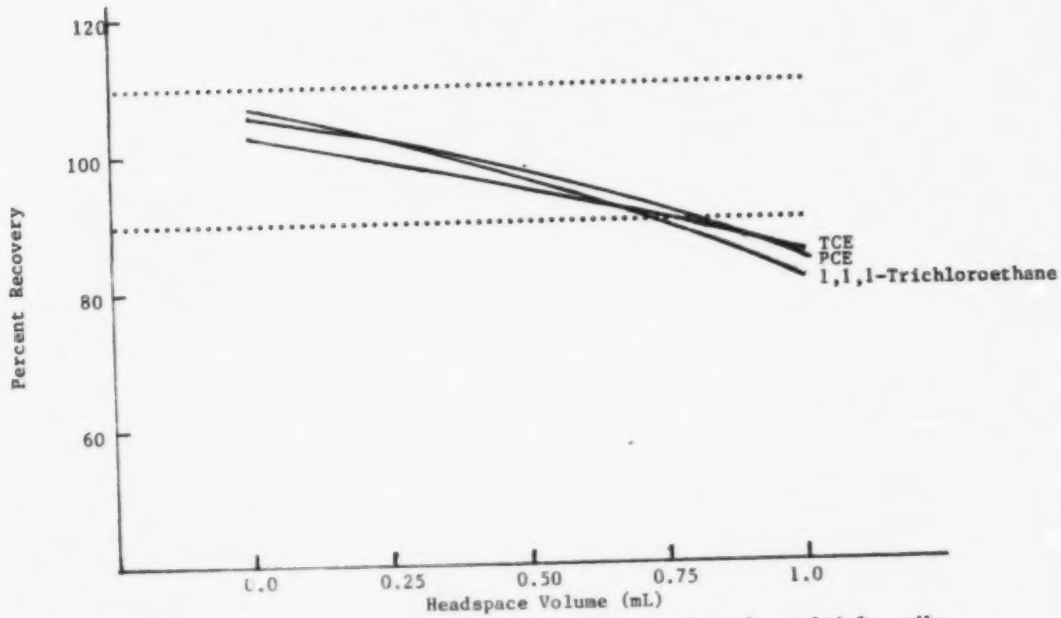

Figure A-2. Percent recovery versus headspace volume for multiple spike samples.

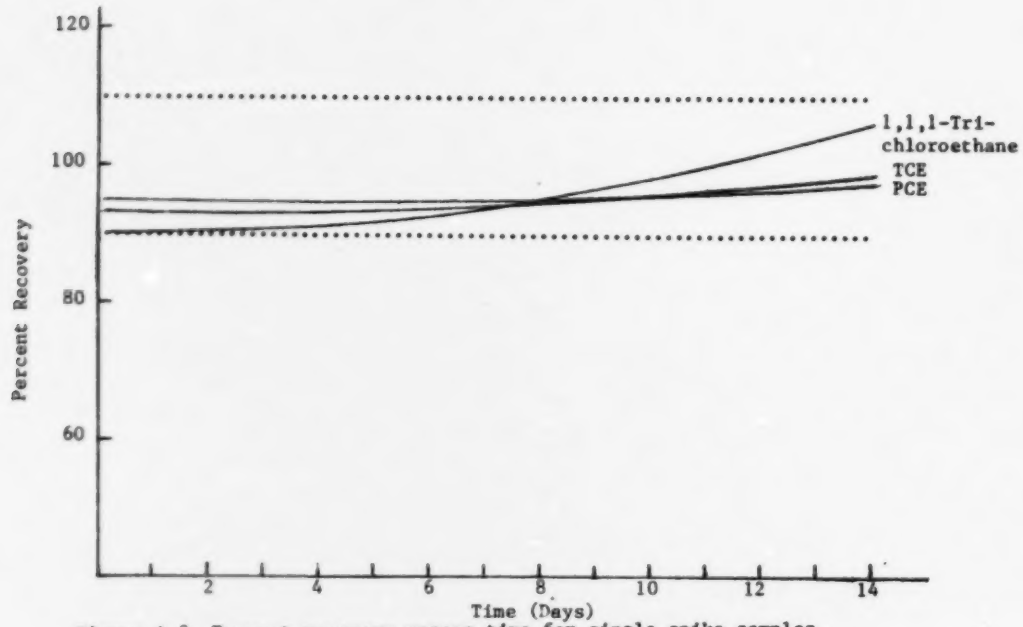

Figure A-3. Percent recovery versus time for single spike samples.

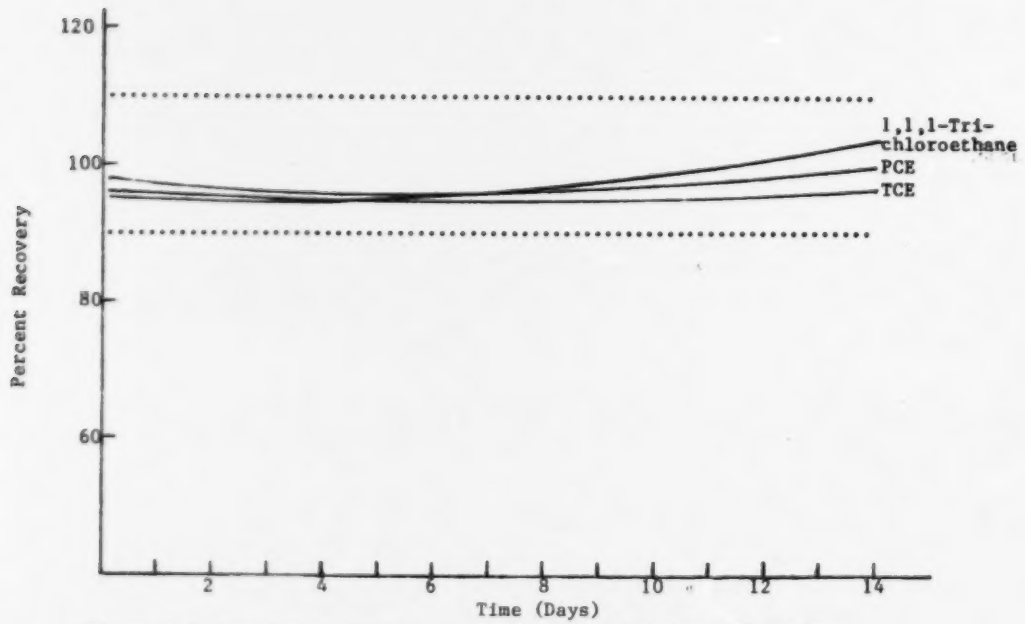

Figure A-4. Percent recovery versus time for multiple spike samples.

TABLE A-1. CONCENTRATIONS OF THE THREE VOCs IN MULTIPLE SPIKE SAMPLES USED FOR HEADSPACE STUDY

Repetition I	
1,1,1-Trichloroethane	46.8 µg/L
TCE	32.8 µg/L
PCE	24.4 µg/L
Mixture	104.0 µg/L
Repetition II	
1,1,1-Trichloroethane	41.8 µg/L
TCE	38.8 µg/L
PCE	32.5 µg/L
Mixture	113.1 µg/L

There was no loss of recovery for holding times up to 14 days. There even appeared to be some improvement in percent recovery versus time; however, the increase is not significant.

A two factor analysis of variance (ANOVA) of the headspace study data appears in Tables A-2 through A-7. ANOVA was used to analyze the variation in percent recovery attributable to headspace volume, holding time, and the interaction between headspace volume and holding time. A random model was used. Therefore, even though the headspace volumes and holding times were fixed for this study, the data can be used to infer the impact of randomly occurring headspace/holding time interactions within their respective ranges.

If the computed F value (F_c) is greater than the tabular F value (F_t), there is a significant effect. F values in Tables A-2 through A-7 show no significant effect caused by holding time. Results for the single spike PCE test (Table A-4) contradict the other results, but incomplete data for a portion of the single PCE spike test biased the ANOVA. It is clear from Figure A-3 that there is little change in PCE recovery from a single spike as a function of time. Consequently, the ANOVA data in Table A-3 will not be used in this discussion.

TABLE A-2. ANALYSIS OF VARIANCE RESULTS FOR 1,1,1-TRICHLOROETHANE RECOVERED FROM A 50 µg/L SPIKE

Source	Large Sum of Squares	Degrees of Freedom	Large Mean Square	F_c[1] (Random Model)	F_t[2] (0.95)
Headspace	53,784	3	17,928	1.33	3.29
Time	171,575	5	34,315	2.55	2.90
Headspace-Time Interaction	202,205	15	13,480	1.06	2.11
Within Cells[3]	305,338	24	12,722	-	-
Total	732,903	46	15,933	-	-

[1] F_c = computed F value.

[2] F_t = F value from table.

[3] Cells are subgroups of data corresponding to specific headspace volumes and holding times.

TABLE A-3. ANAYLSIS OF VARIANCE RESULTS FOR TRICHLOROETHYLENE RECOVERED FROM A 50 µg/L SPIKE

Source	Large Sum of Squares	Degrees of Freedom	Large Mean Square	F_c[1] (Random Model)	F_t[2] (0.95)
Headspace	56,243	3	18,748	24.22	3.29
Time	8,729	5	1,746	2.26	2.90
Headspace-Time Interaction	11,611	15	774	0.04	2.11
Within Cells[3]	444,328	24	18,597	-	-
Total	523,474	47	11,138	-	-

[1] F_c = computed F value.

[2] F_t = F value from table.

[3] Cells are subgroups of data corresponding to specific headspace volumes and holding times.

TABLE A-4. ANALYSIS OF VARIANCE RESULTS FOR TETRACHLOROETHYLENE RECOVERED FROM A 20 µg/L SPIKE

Source	Large Sum of Squares	Degrees of Freedom	Large Mean Square	F_c[1] (Random Model)	F_t[2] (0.95)
Headspace	483,459	3	161,153	5.74	3.29
Time	713,441	5	142,688	5.09	2.90
Headspace-Time Interaction	420,819	15	28,055	0.51	2.11
Within Cells[3]	-1,309,749	24	-54,573	-	-
Total	307,970	36	7,897	-	-

[1] F_c = computed F value.

[2] F_t = F value from table.

[3] Cells are subgroups of data corresponding to specific headspace volumes and holding times.

TABLE A-5. ANALYSIS OF VARIANCE RESULTS FOR 1,1,1-TRICHLOROETHANE RECOVERED FROM 20/50/50 µg/L MIXTURE OF TETRACHLOROETHYLENE, 1,1,1-TRICHLOROETHANE, AND TRICHLOROETHYLENE

Source	Large Sum of Squares	Degrees of Freedom	Large Mean Square	F_c[1] (Random Model)	F_t[2] (0.95)
Headspace	178,404	3	59,468	11.83	3.29
Time	63,476	5	12,695	2.53	2.90
Headspace-Time Interaction	75,396	15	5,026	2.33	2.11
Within Cells[3]	51,840	24	2,160	-	-
Total	369,116	47	7,853	-	-

[1] F_c = computed F value.

[2] F_t = F value from table.

[3] Cells are subgroups of data corresponding to specific headspace volumes and holding times.

TABLE A-6. ANALYSIS OF VARIANCE RESULTS FOR TRICHLOROETHYLENE RECOVERED FROM A 20/50/50 µg/L MIXTURE OF TETRACHLOROETHYLENE, 1,1,1-TRICHLOROETHANE, AND TRICHLOROETHYLENE

Source	Large Sum of Squares	Degrees of Freedom	Large Mean Square	F_c[1] (Random Model)	F_t[2] (0.95)
Headspace	89,683	3	29,894	13.79	3.01
Time	18,435	5	3,687	1.70	2.62
Headspace-Time Interaction	32,513	15	2,168	0.71	2.11
Within Cells[3]	73,080	24	3,045	-	-
Total	213,711	47	4,547	-	-

[1] F_c = computed F value.

[2] F_t = F value from table.

[3] Cells are subgroups of data corresponding to specific headspace volumes and holding times.

TABLE A-7. ANALYSIS OF VARIANCE RESULTS FOR TETRACHLOROETHYLENE RECOVERED FROM A 20/50/50 µg/L MIXTURE OF TETRACHLOROETHYLENE, 1,1,1-TRICHLOROETHANE, AND TRICHLOROETHYLENE

Source	Large Sum of Squares	Degrees of Freedom	Large Mean Square	F_c[1] (Random Model)	F_t[2] (0.95)
Headspace	197,331	3	65,777	3.19	3.29
Time	24,413	5	4,883	0.24	2.90
Headspace-Time Interaction	309,687	15	20,646	1.98	2.11
Within Cells[3]	249,791	24	10,408	-	-
Total	781,222	46	16,983	-	-

[1] F_c = computed F value.

[2] F_t = F value from table.

[3] Cells are subgroups of data corresponding to specific headspace volumes and holding times.

Three of the five remaining tables show a significant headspace effect, but none show a holding time effect. There is not apparent headspace/holding time interaction. The fact that there is no trend of significant headspace/time interaction means that the effect of headspace on recovery is independent of holding time.

Figure A-1 and A-2 indicate that the headspace effect may be more pronounced for the multiple spike. The multiple spike best reflects the composition of raw water samples for this study. Consequently, it was determined that the headspace effect was only significant in raw water samples with headspace volumes greater than 0.5 mLs. Data from raw water samples with greater than 0.5 mLs headspace were not used in this report.

APPENDIX B.

VOC AND MICROBIOLOGICAL RESULTS FOR POINT-OF-USE EFFLUENT SAMPLES - SILVERDALE

SILVERDALE VOC RESULTS

Concentration (µg/L)

Model A

LOCATION /Flow	DATE	TRI-CHLORO-ETHYLENE	TETRA-CHLORO-ETHYLENE	1,1,1-TRI-CHLORO-ETHANE	1,2-DI-CHLORO-ETHANE	CARBON TETRA-CHLORIDE	CHLORO-FORM	BROMODI-CHLORO-METHANE	CHLORO-DIBROMO-METHANE	Bromoform	Methylene Chloride
8/21	3/14/83	ND[1]	ND	-[2]	-	-	-	-	-	-	-
26	3/21/83	ND	ND	-	-	-	-	-	-	-	-
104	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
209	11/7/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
13/8	3/14/83	ND	ND	-	-	-	-	-	-	-	-
11	3/21/83	ND	ND	-	-	-	-	-	-	-	-
42	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
82	9/12/83	ND	ND	ND	ND	ND	1	ND	ND	ND	-
19/28	3/14/83	ND	ND	-	-	-	-	-	-	-	-
42	4/18/83	ND	ND	-	-	-	-	-	-	-	-
76	7/11/83	ND	ND	-	-	-	ND	ND	ND	ND	-
117	10/10/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
26/34	3/7/83	ND	ND	-	-	-	-	-	-	-	-
126	5/16/83	ND	ND	-	-	-	-	-	-	-	-
233	8/15/83	ND	ND	ND	-	ND	ND	ND	ND	ND	-
274	10/17/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
35/28	3/14/83	ND	ND	-	-	-	-	-	-	-	-
71	4/18/83	ND	ND	-	-	-	-	-	-	-	-
304	8/15/83	ND	ND	ND	-	ND	ND	ND	ND	ND	-
408	10/17/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
440	11/7/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
46/											
38	4/18/83	ND	ND	-	-	-	-	-	-	-	-
86	8/15/83	ND	ND	ND	-	ND	ND	ND	ND	ND	-
109	10/17/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
52											
66	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
91	8/15/83	ND	ND	ND	-	ND	ND	ND	ND	ND	-
93	10/17/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
55											
36	3/21/83	ND	ND	-	-	-	-	-	-	-	-
310	10/10/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
64											
36	5/16/83	ND	ND	-	-	-	-	-	-	-	-
104	9/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
67165	5/16/83	ND	ND	-	-	-	-	-	-	-	-
422	9/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-

[1] ND - not detected

[2] - not analyzed for

SILVERDALE VOC RESULTS

Concentration (µg/L)

Model C

LOCATION /Flow	DATE	TRI-CHLORO-ETHYLENE	TETRA-CHLORO-ETHYLENE	1,1,1-TRI-CHLORO-ETHANE	1,2-DI-CHLORO-ETHANE	CARBON TETRA-CHLORIDE	CHLORO-FORM	BROMODI-CHLORO-METHANE	CHLORO-DIBROMO-METHANE	Bromoform	Methylene Chloride
11/41	3/14/83	ND[1]	ND	-[2]	-	-	-	-	-	-	-
41	3/21/83	ND	ND	-	-	-	-	-	-	-	-
123	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
40[3]	9/12/83	ND	ND	ND	ND	ND	2.	ND	ND	ND	-
89	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
139	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
128	3/12/84	ND	ND	0.6	-	ND	2.0	ND	ND	ND	ND
192	4/2/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
16/11	3/14/83	ND	ND	-	-	-	-	-	-	-	-
32	4/18/83	18	3	-	-	-	-	-	-	-	-
89	7/11/83	19	3	ND	-	-	.1	ND	ND	ND	-
36[3]	10/10/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
71	12/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
108	2/6/84	ND	ND	ND	-	ND	ND	ND	ND	ND	0.7
149	4/9/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
20/46	3/14/83	ND	ND	-	-	-	-	-	-	-	-
100	4/18/83	ND	ND	-	-	-	-	-	-	-	-
226	7/11/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
10[3]	9/12/83	ND	ND	ND	ND	ND	1	ND	ND	ND	-
36	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
54	2/6/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
130	4/9/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
28/43	3/14/83	ND	ND	-	-	-	-	-	-	-	-
121	5/16/83	ND	ND	-	-	-	-	-	-	-	-
20[3]	8/15/83	ND	ND	ND	-	ND	ND	ND	ND	ND	-
158	10/17/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
185	11/7/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
303	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
348	2/13/84	1.0	ND	1.2	-	ND	4.2	ND	ND	ND	-
383	3/5/84	ND	ND	ND	-	0.5	0.6	ND	ND	ND	ND
32/18	3/14/83	ND	ND	-	-	-	-	-	-	-	-
64	5/16/83	ND	ND	-	-	-	-	-	-	-	-
13[3]	8/15/83	ND	ND	ND	-	ND	ND	ND	ND	ND	-
187	12/5/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
237	1/9/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
313	3/12/84	ND	ND	ND	-	ND	0.6	ND	ND	ND	4.0
336	4/2/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
42/136	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
99[3]	9/12/83	ND	ND	ND	-	-	1	ND	ND	ND	-
227	11/7/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
256	12/5/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
367	2/13/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-

[1] ND - not detected

[2] - not analyzed for

[3] - new cartridge

SILVERDALE VOC RESULTS

Concentration (μg/L)

Model C (cont.)

LOCATION /Flow	DATE	TRI-CHLORO-ETHYLENE	TETRA-CHLORO-ETHYLENE	1,1,1-TRI-CHLORO-ETHANE	1,2-DI-CHLORO-ETHANE	CARBON TETRA-CHLORIDE	CHLORO-FORM	BROMODI-CHLORO-METHANE	CHLORO-DIBROMO-METHANE	Bromoform	Methylene Chloride
42/394	3/5/84	ND[1]	ND	ND	-[2]	ND	ND	ND	ND	ND	ND
44/43	4/18/83	ND	ND	-	-	-	-	-	-	-	-
8[3]	8/15/83	ND	ND	ND	-	ND	ND	ND	ND	ND	-
46	11/7/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
100	2/13/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
106	3/5/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
49/51	3/21/83	ND	ND	-	-	-	-	-	-	-	-
146	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
101[3]	10/10/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
163	12/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
217	2/6/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
279	4/9/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
60 118	5/16/83	ND	ND	-	-	-	-	-	-	-	-
29[3]	9/12/83	ND	ND	ND	ND	ND	1	ND	ND	ND	-
55	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
62	12/5/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
111	4/12/84	ND	ND	ND	-	0.7	0.5	ND	ND	ND	ND

[1] ND - not detected

[2] - not analyzed for

[3] - new cartridge

SILVERDALE VOC RESULTS

Concentration (µg/L)

Model D

LOCATION /Flow	DATE	TRI-CHLORO-ETHYLENE	TETRA-CHLORO-ETHYLENE	1,1,1-TRI-CHLORO-ETHANE	1,2-DI-CHLORO-ETHANE	CARBON TETRA-CHLORIDE	CHLORO-FORM	BROMODI-CHLORO-METHANE	CHLORO-DIBROMO-METHANE	Bromoform	Methylene Chloride
5/62	3/21/83	ND	ND[1]	-[2]	-	-	-	-	-	-	-
181	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
398	10/10/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
445	12/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
485	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
503	2/6/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
551	4/9/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
15/31	3/14/83	ND	ND	-	-	-	-	-	-	-	-
37	4/18/83	ND	ND	-	-	-	-	-	-	-	-
64	7/11/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
109	10/10/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
125	12/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
138	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
142	2/6/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
201	4/9/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
18/21	3/14/83	ND	ND		-	-	-	-	-	-	-
31	4/18/83	ND	ND		-	-	-	-	-	-	-
82	7/11/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
135	10/10/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
172	12/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
199	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
201	2/6/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
237	4/9/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
25/63	3/14/83	ND	ND	-	-	-	-	-	-	-	-
113	5/16/83	ND	ND	-	-	-	-	-	-	-	-
197	8/15/83	ND	ND	ND	-	ND	ND	ND	ND	ND	-
255	11/2/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
291	12/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
311	1/9/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
335	2/13/84	0.6	ND	0.8	-	ND	1.6	ND	ND	ND	-
359	3/5/84	ND	ND	1.0	-	0.8	5.0	ND	ND	ND	ND
27/49	3/14/83	ND	ND	-	-	-	-	-	-	-	-
112	5/16/83	ND	ND	-	-	-	-	-	-	-	-
213	8/15/83	ND	ND	ND	-	ND	ND	ND	ND	ND	-
298	10/17/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
321	11/7/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
401	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
449	2/13/84	0.6	ND	0.8	-	ND	1.3	ND	ND	ND	-
460	3/5/84	ND	ND	ND	-	0.6	0.8	ND	ND	ND	1.3
36/51	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
211	10/17/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
225	11/7/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-

[1] ND - not detected

[2] - not analyzed for

SILVERDALE VOC RESULTS

Concentration (µg/L)

Model D (cont.)

LOCATION /Flow	DATE	TRI-CHLORO-ETHYLENE	TETRA-CHLORO-ETHYLENE	1,1,1-TRI-CHLORO-ETHANE	1,2-DI-CHLORO-ETHANE	CARBON TETRA-CHLORIDE	CHLORO-FORM	BROMODI-CHLORO-METHANE	CHLORO-DIBROMO-METHANE	Bromoform	Methylene Chloride
36/239	12/5/83	ND	ND[1]	ND	ND	ND	ND	ND	ND	ND	-[2]
243	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
246	2/13/84	ND	ND	1.2	-	ND	1.0	ND	ND	ND	-
/NA	4/18/83	ND	ND	-	-	-	-	-	-	-	-
255	7/11/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
398	10/17/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
435	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
495	2/13/84	ND	ND	ND	-	0.7	ND	ND	ND	ND	-
501	3/5/84	ND	ND	ND	-	0.6	ND	ND	ND	ND	ND
50/31	4/18/83	ND	ND	-	-	-	-	-	-	-	-
64	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
160	10/10/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
254	2/6/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
328	4/9/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
59/349	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
660	9/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
831	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
895	12/5/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
1123	3/12/84	ND	ND	ND	-	ND	ND	ND	ND	ND	0.6
1126	4/2/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
66/171	5/16/83	ND	ND	-	-	-	-	-	-	-	-
463	9/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
607	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
655	12/5/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
835	3/12/84	ND	ND	0.7	-	0.5	1.4	ND	ND	ND	ND
878	4/2/84	ND	ND	ND	-	ND	1.1	ND	ND	ND	ND

[1] ND - not detected

[2] - not analyzed for

[3] NA - not available

SILVERDALE VOC RESULTS

Concentration (µg/L)

Model E

LOCATION /Flow	DATE	TRI-CHLORO-ETHYLENE	TETRA-CHLORO-ETHYLENE	1,1,1-TRI-CHLORO-ETHANE	1,2-DI-CHLORO-ETHANE	CARBON TETRA-CHLORIDE	CHLORO-FORM	BROMODI-CHLORO-METHANE	CHLORO-DIBROMO-METHANE	Bromoform	Methylene Chloride
6/38	3/14/83	ND	ND[1]	-[2]	-	-	-	-	-	-	-
46	3/21/83	ND	ND	-	-	-	-	-	-	-	-
156	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
398	10/10/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
487	12/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
546	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
577	2/6/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
662	4/9/84	ND	ND	ND	-	ND	ND	ND	ND	ND	0.7
8/113	12/12/83	21.5	7.4	ND	ND	ND	ND	ND	ND	ND	-
152	1/16/84	24.3	3.5	ND	ND	ND	ND	ND	ND	ND	-
176	2/6/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
85	4/9/84	ND	ND	ND	-	ND	ND	ND	ND	ND	202
12/31	3/14/83	ND	ND	-	-	-	-	-	-	-	-
35	3/21/83	ND	ND	-	-	-	-	-	-	-	-
131	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
408	11/14/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
490	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
608	3/12/84	ND	ND	ND	-	ND	ND	ND	ND	ND	0.6
656	4/2/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
13/8	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
28	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
52	3/20/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
61	4/2/84	ND	ND	ND	-	ND	ND	ND	ND	ND	133
17 /8	3/14/83	ND	ND	-	-	-	-	-	-	-	-
68	4/18/83	ND	ND	-	-	-	-	-	-	-	-
182	7/11/83	3	ND	ND	-	-	ND	ND	ND	ND	-
295	10/10/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
353	12/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
400	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
425	2/6/84	ND	ND	ND	-	ND	16.7	3.1	ND	ND	-
482	4/9/84	ND	ND	ND	-	ND	ND	ND	ND	ND	1.6
19 /0	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
27	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
87	4/9/84	ND	ND	ND	-	ND	ND	ND	ND	ND	30.1
21/69	3/14/83	ND	ND	-	-	-	-	-	-	-	-
150	5/16/83	ND	ND	-	-	-	-	-	-	-	-
235	7/11/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
278	8/15/83	ND	ND	ND	-	ND	ND	ND	ND	ND	-
373	12/5/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
413	1/16/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
451	3/12/84	ND	ND	ND	-	ND	ND	ND	ND	ND	4.8
466	4/2/84	ND	ND	ND	-	1.1	ND	ND	ND	ND	4.7

[1] ND - not detected

[2] - not analyzed for

SILVERDALE VOC RESULTS

Concentration (µg/L)

Model E (cont.)

LOCATION /Flow	DATE	TRI-CHLORO-ETHYLENE	TETRA-CHLORO-ETHYLENE	1,1,1-TRI-CHLORO-ETHANE	1,2-DI-CHLORO-ETHANE	CARBON TETRA-CHLORIDE	CHLORO-FORM	BROMODI-CHLORO-METHANE	CHLORO-DIBROMO-METHANE	Bromoform	Methylene Chloride
26/8	12/5/83	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	-[2]
25	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
27	2/13/84	0.6	ND	0.8	-	ND	0.7	ND	ND	ND	-
49	3/5/84	ND	ND	ND	-	0.5	1.2	ND	ND	ND	12.3
30/NA[3]	3/14/83	ND	ND	-	-	-	-	-	-	-	-
105	5/16/83	ND	ND	-	-	-	-	-	-	-	-
240	8/15/83	12	4	ND	-	1	ND	ND	ND	ND	-
342	10/17/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
403	12/5/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
456	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
522	3/12/84	ND	ND	ND	-	ND	0.6	ND	ND	ND	10.0
554	4/2/84	ND	ND	ND	-	ND	ND	ND	ND	ND	0.6
35/98	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
143	2/13/84	6.1	ND	1.6	-	ND	2.3	ND	ND	ND	-
168	3/5/84	ND	ND	ND	-	ND	ND	ND	ND	ND	259
41/63	4/18/83	3	ND	-	-	-	-	-	-	-	-
428	8/15/83	ND	ND	ND	-	ND	ND	ND	ND	ND	-
549	10/17/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
638	11/7/83	19.0	4.5	ND	ND	4.7	ND	ND	ND	ND	-
41[4]	1/9/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
117	2/13/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
168	3/5/84	ND	ND	ND	-	0.5	ND	ND	ND	ND	105
46/9	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
51	2/13/84	ND	ND	1.4	-	ND	ND	ND	ND	ND	-
48/82	4/18/83	ND	ND	-	-	-	-	-	-	-	-
156	7/11/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
200	10/10/83	22.2	2.7	ND	ND	1.5	1.4	ND	ND	ND	-
247	12/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
282	2/6/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
332	4/9/84	ND	ND	ND	-	ND	ND	ND	ND	ND	324
52/1	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
26	1/9/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
33	2/13/84	ND	ND	0.7	-	ND	0.7	ND	ND	ND	-
54/63	3/21/83	ND	ND	-	-	-	-	-	-	-	-
365	7/11/83	ND	ND	ND	-	ND	ND	ND	ND	ND	-
597	11/7/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
648	12/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
707	2/13/84	ND	ND	ND	-	ND	2.8	ND	ND	ND	-
730	3/12/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
55/2	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
108	2/6/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
177	4/9/84	ND	ND	ND	-	ND	ND	ND	ND	ND	324

[1] ND - not detected

[2] - not analyzed for

[3] NA - not available

[4] - new cartridge

SILVERDALE VOC RESULTS

Concentration (µg/L)

Model E (cont.)

LOCATION /Flow	DATE	TRI-CHLORO-ETHYLENE	TETRA-CHLORO-ETHYLENE	1,1,1-TRI-CHLORO-ETHANE	1,2-DI-CHLORO-ETHANE	CARBON TETRA-CHLORIDE	CHLORO-FORM	BROMODI-CHLORO-METHANE	CHLORO-DIBROMO-METHANE	Bromoform	Methylene Chloride
56/43	6/13/83	ND[1]	ND	ND	-[2]	-	ND	ND	ND	ND	-
68	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
94	12/5/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
130	3/12/84	ND	ND	ND	-	ND	ND	ND	ND	ND	16.2
136	4/2/84	ND	ND	ND	-	ND	ND	ND	ND	ND	53.0
64/1	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
9	12/5/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
63	3/12/84	ND	ND	ND	-	ND	ND	ND	ND	ND	9.6
74	4/2/84	ND	ND	ND	-	ND	1.6	ND	ND	ND	348.0
67/11	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
38	12/5/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
204	3/12/84	ND	ND	0.7	-	0.5	0.6	ND	ND	ND	30.5
242	4/2/84	ND	ND	ND	-	ND	0.9	ND	ND	ND	166.0
68 /14	3/7/83	ND	ND	-	-	-	-	-	-	-	-
66	5/16/83	ND	ND	-	-	-	-	-	-	-	-
207	9/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
227	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
236	12/5/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
304	3/12/84	ND	ND	ND	-	ND	ND	ND	ND	ND	9.8
326	4/2/84	ND	ND	ND	-	ND	ND	ND	ND	-	6.4

[1] ND - not detected

[2] - not analyzed for

SILVERDALE VOC RESULTS

Concentration (µg/L)

Model F

LOCATION /Flow	DATE	TRI-CHLORO-ETHYLENE	TETRA-CHLORO-ETHYLENE	1,1,1-TRI-CHLORO-ETHANE	1,2-DI-CHLORO-ETHANE	CARBON TETRA-CHLORIDE	CHLORO-FORM	BROMODI-CHLORO-METHANE	CHLORO-DIBROMO-METHANE	Bromoform	Methylene Chloride
3/31	5/16/83	ND[1]	ND	-[2]	-	-	-	-	-	-	-
44	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
81	8/15/83	ND	ND	ND	-	ND	ND	ND	ND	ND	-
86	10/10/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
103	12/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
107	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
108	2/6/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
121	4/9/84	ND	ND	ND	-	ND	ND	ND	ND	ND	0.9
4/24	3/14/83	ND	ND	-	-	-	-	-	-	-	-
36	3/21/83	ND	ND	-	-	-	-	-	-	-	-
181	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
306	10/10/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
375	12/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
426	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
456	2/6/54	ND	ND	ND	-	ND	ND	ND	ND	ND	-
533	4/2/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
14/20	3/14/83	ND	ND	-	-	-	-	-	-	-	-
38	3/21/83	ND	ND	-	-	-	-	-	-	-	-
109	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
214	9/12/83	ND	ND	ND	ND	ND	2	ND	ND	ND	-
271	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
314	1/9/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
420	3/12/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
NA[3]	4/2/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
22/17	3/14/83	ND	ND	-	-	-	-	-	-	-	-
48	4/18/83	ND	ND	-	-	-	-	-	-	-	-
112	8/15/83	ND	ND	ND	-	ND	ND	ND	ND	ND	-
151	10/17/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
170	12/5/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
196	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
239	3/12/84	ND	ND	ND	-	0.6	0.6	ND	ND	ND	ND
242	4/2/84	ND	ND	ND	-	ND	6.6	ND	ND	ND	ND
34/05	3/7/83	ND	ND	-	-	-	-	-	-	-	-
25	4/18/83	ND	ND	-	-	-	-	-	-	-	-
54	7/11/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
87	9/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
107	10/17/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
110	11/7/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
143	1/16/84	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
156	2/13/84	2.5	ND	1.6	-	ND	1.3	ND	ND	ND	-
165	3/5/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
43/120	4/18/83	ND	ND	-	-	-	-	-	-	-	-

[1] ND - not detected

[2] - not analyzed for

[3] NA - not available

SILVERDALE VOC RESULTS

Concentration (µg/L)

Model F (cont.)

LOCATION /Flow	DATE	TRI-CHLORO-ETHYLENE	TETRA-CHLORO-ETHYLENE	1,1,1-TRI-CHLORO-ETHANE	1,2-DI-CHLORO-ETHANE	CARBON TETRA-CHLORIDE	CHLORO-FORM	BROMODI-CHLORO-METHANE	CHLORO-DIBROMO-METHANE	Bromoform	Methylene Chloride
43/316	7/11/83	ND[1]	ND	ND	-[2]	-	ND	ND	ND	ND	-
568	10/17/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
603	11/7/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
721	2/13/84	ND	ND	ND	-	ND	ND	ND	ND	ND	-
51/130	7/11/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
130	10/10/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
137	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
152	4/9/84	ND	ND	ND	-	ND	ND	ND	ND	ND	1.4
53/11	6/13/83	ND	ND	ND	-	-	ND	ND	ND	ND	-
17	8/15/83	ND	ND	ND	-	ND	ND	ND	ND	ND	-
23	11/7/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
31	12/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
37	2/13/84	ND	ND	ND	-	ND	1.4	ND	ND	ND	-
49	3/5/84	ND	ND	ND	-	0.6	ND	ND	ND	ND	ND
61/125	5/16/83	ND	ND	-	-	-	-	-	-	-	-
186	10/10/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
193	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
193	12/5/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
290	3/12/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
330	4/2/84	ND	ND	ND	-	ND	ND	ND	ND	ND	ND
65/NA[3]	5/16/83	ND	ND	-	-	-	-	-	-	-	-
294	9/12/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
369	11/14/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
387	12/5/83	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
518	3/12/84	ND	ND	ND	-	ND	ND	ND	ND	ND	0.8
545	4/2/84	ND	ND	ND	-	ND	0.7	ND	ND	ND	ND

[1] ND - not detectable

[2] - not analyzed for

[3] NA - not available

SILVERDALE MICROBIOLOGICAL DATA

Standard Plate Count Results (#/ml)

Model A

Location /Flow	Date	Unflushed/Un-Disinfected Tap	Flushed/Dis-Infected Tap	1 L Flushed/ Disinfected Tap
8/21	3/14/83	1300		
26	3/21/83	1200		
104	6/13/83	5800		
209	11/2/83	35	1	
13/8	3/14/83	3700		
11	3/21/83	5800		
42	6/13/83	5800		
82	9/12/83	3100	1	
19/28	3/14/83	480		
42	4/18/83	590		
76	7/11/83	3100		
117	10/10/83	5800	190	
26/34	3/7/83	600		
126	5/16/83	1800		
233	8/15/83	470	730	
35/28	3/14/83	2700		
71	4/18/83	88		
304	8/15/83	1000	2	
	11/7/83	110	1	
46 /0	2/28/83	4100		
38	4/18/83	3200		
86	8/15/83	5700	2300	
52/10	3/4/83	4200		
66	6/13/83	2900		
91	8/15/83	2800	2	
55 /10	2/28/83	>5800		
36	3/14/84	5800		
NA[1]	7/11/83	3400		
310	10/10/83	130	81	
64 /0	2/28/83	1900		
36	5/16/83	4800		
104	9/12/83	5800	410	
67 /NA[1]	2/28/83	5100		
165	5/16/83	2100		
207	9/12/83	360	3	

[1] NA - not available

SILVERDALE MICROBIOLOGICAL DATA

Standard Plate Count Results (#/ml)

Model C

Location /Flow	Date	Unflushed/Un-Disinfected Tap	Flushed/Dis-Infected Tap	1 L Flushed/ Disinfected Tap
11/41	3/14/83	190		
41	3/21/83	39		
123	6/8/83	240		
40	9/12/83	1300	11	
139	1/16/84	2	8	
192	4/2/84		2	1600
16/11	3/14/83	1600		
32	4/18/83	1200		
89	7/11/83	340		
36[1]	10/10/83	1600	54	
94	1/16/84	290	1	
108	2/6/84	490	1	
20/46	3/14/83	5800		
100	4/18/83	1600		
226	7/11/83	980		
10[1]	9/12/83	3200	160	
14	10/10/83	3100	23	
36	1/16/83	1100	8	
54	2/6/83	4100	42	
28/43	3/14/83	540		
121	5/16/83	3900		
20[1]	8/15/83	2900	490	
185	11/7/83	3600	5	
303	1/16/83	830	2	
383	3/5/84		1	11
32/18	3/14/83	4900		
64	5/16/83	3200		
13[1]	8/15/83	560	6	
111	12/5/83	350	11	
237	1/9/84	630	16	
336	4/2/84		4	360
42/30	3/7/83	5800		
136	6/13/83	1200		
99[1]	9/12/83	1100	49	
256	12/5/83	250	2	
325	1/23/84	31	1	
394	3/5/84	3	3	5
44/0	2/28/83	1200		
43	4/18/83	1900		
8[1]	8/15/83	5800	1300	
46	11/7/83	2800	230	
89	1/23/84	2100	47	
106	3/5/84		32	290
49/20	2/28/83	2200		

[1] new cartridge

SILVERDALE MICROBIOLOGICAL DATA

Standard Plate Count Results (#/ml)

Model C (cont.)

Location /Flow	Date	Unflushed/Un-Disinfected Tap	Flushed/Dis-Infected Tap	1 L Flushed/ Disinfected Tap
49/51	3/21/83	600		
146	6/13/83	900		
101[1]	10/10/83	1400	3	
195	1/23/84	780	1	
217	2/6/84	110	3	
60/10	2/28/83	2700		
48	5/16/83	5800		
29[1]	9/12/83	5800	210	
55	12/5/83	1300	120	
84	1/23/84	83	24	
111	4/2/84		28	170

[1] new cartridge

SILVERDALE MICROBIOLOGICAL DATA

Standard Plate Count Results (#/ml)

Model D

Location /Flow	Date	Unflushed/Un-Disinfected Tap	Flushed/Dis-Infected Tap	1 L Flushed/ Disinfected Tap
5 /44	3/7/83	1300		
62	3/21/83	2700		
181	6/13/83	4200		
398	10/16/83	5100	310	
485	1/16/84	3700	120	
503	2/6/84	4200	160	
15 /31	3/14/83	4900		
37	4/18/83	2700		
64	7/11/83	1400		
109	10/10/83	5800	140	
138	1/16/84	5800	310	
142	2/6/84	5800	530	
18 /21	3/14/83	5300		
31	4/18/83	5800		
82	7/11/83	2700		
135	10/10/83	4900	130	
199	1/16/84	5800	2900	
201	2/6/84	2600	1100	
25 /63	3/14/83	600		
113	5/16/83	1300		
197	8/15/83	5100	1200	
255	11/7/83	2100	620	
311	1/9/84	5800	540	
359	3/5/84		480	1300
27 /49	3/14/83	4300		
112	5/16/83	2700		
213	8/15/83	5800	4200	
321	11/7/83	2900	730	
401	1/16/84	3200	660	
460	3/5/84		120	3500
36 /51	6/13/83	1400		
152	8/15/83	5500	560	
225	11/7/83	5800	2300	
239	12/5/83	5800	900	
243	1/16/84	5800	3200	
168	3/5/84		420	1500
45 /30	2/28/83	1400		
NA[1]	4/18/83	660		
255	7/11/83	720		
435	11/7/83	540	540	
494	1/23/84	5800	270	
501	3/5/84		690	5800
50 /10	2/28/83	700		
32	4/18/83	180		
130	6/13/83	1000		

[1] NA - not available

SILVERDALE MICROBIOLOGICAL DATA

Standard Plate Count Results (#/ml)

Model D (cont.)

Location /Flow	Date	Unflushed/Un-Disinfected Tap	Flushed/Dis-Infected Tap	1 L Flushed/ Disinfected Tap
130	10/10/83	5800	480	
231	1/23/84	5800	130	
254	2/6/84	1500	110	
59 /60	2/28/83	1200		
349	6/13/83	1000		
660	9/12/83	3400	190	
875	12/5/83	1100	510	
988	1/23/84	140	6	
1176	4/2/84		24	110
66 /60	2/28/83	3900		
171	5/16/83	1900		
463	9/12/83	5800	600	
655	12/5/83	5800	550	
752	1/23/84	1400	180	
878	4/2/84		1500	3900

SILVERDALE MICROBIOLOGICAL DATA

Standard Plate Count Results (#/ml)

Model E

Location /Flow	Date	Unflushed/Un-Disinfected Tap	Flushed/Dis-Infected Tap	1 L Flushed/ Disinfected Tap
6/138	3/14/83	1		
46	3/21/83	180		
156	6/13/83	1200		
398	10/10/83	5800	16	
546	1/16/84	2100	8	
577	2/6/84	1000	4	
8/152	1/16/84	1200	6	
176	2/6/84	540	3	
12/131	3/14/83	5200		
35	3/21/83	5800		
131	6/13/83	3600		
291	9/12/83	2900	4	
490	1/16/84	480	4	
656	4/2/84		3	9
13/28	1/16/84	4100	2	
61	4/2/84		1	7
17/8	3/14/83	1700		
68	4/18/83	600		
182	7/11/83	5800		
295	10/10/83	1300	4	
400	1/16/84	600	1	
425	2/6/84	1300	3	
19/36	1/16/84	130	1	
49	2/6/84	2200	5	
21/69	3/14/83	1900		
150	5/16/83	5800		
235	7/11/83	5100		
278	8/15/83	5800	9	
373	12/5/83	4800	16	
413	1/16/84	4900	6	
466	4/2/84		490	2100
26/8	12/5/83	1300	580	
25	1/16/84	5800	8	
49	3/5/84		6	480
30/N6	3/16/83	5800		
105	5/16/83	5800		
240	8/15/83	3700	280	
403	12/5/83	4100	2	
456	1/16/84	5100	5	
554	4/2/84		5	4900
35/98	1/16/84	3900	3	
168	3/5/84		3	330
41/20	2/28/83	2300		
63	4/18/43	660		
428	8/15/83	5600	120	

[1] not available

SILVERDALE MICROBIOLOGICAL DATA

Standard Plate Count Results (#/ml)

Model E (cont.)

Location /Flow	Date	Unflushed/Un-Disinfected Tap	Flushed/Dis-Infected Tap	1 L Flushed/ Disinfected Tap
41/638	11/7/83	1500	6	
41[1]	1/9/84	4100	9	
168	3/5/84		81	900
46 /36	1/23/84	810	59	
64	3/5/84		4	310
48 /10	2/28/83	300		
82	4/18/83	2700		
156	7/11/83	1100		
200	10/10/83	5600	12	
271	1/23/84	3200	6	
282	2/6/84	1200	1	
52 /1	11/14/84	5800	1300	
26	1/9/84	1900	52	
46	3/5/84		180	280
54 /30	2/28/83	110		
63	3/21/83	5800		
365	7/11/83	1700		
597	11/7/83	230	1	
691	1/23/84	1200	1	
730	3/5/84		1	16
55/89	1/23/84	280	4	
108	2/6/84	900	1	
56/10	2/28/83	1		
43	6/13/83	5800		
68	9/12/83	4000	81	
94	12/5/83	2900	8	
118	1/23/84	2200	38	
136	4/2/84		26	1400
64/9	12/5/83	5200	3	
30	1/23/84	5800		
74	4/2/84		2	380
67/38	12/5/83	720	23	
118	1/23/84	480	1	
242	4/2/84		1	1
68/14	3/7/83	5800		
66	5/13/83	3600		
207	9/12/83	1300	2	
236	12/5/83	5800	15	
263	1/23/84	5800	4	
326	4/2/84		2	370

[1] new cartridge

SILVERDALE MICROBIOLOGICAL DATA

Standard Plate Count Results (#/ml)

Model F

Location /Flow	Date	Unflushed/Un-Disinfected Tap	Flushed/Dis-Infected Tap	1 L Flushed/ Disinfected Tap
3 /31	5/16/83	5800		
44	6/13/83	5800		
81	8/15/83	5800	49	
86	10/10/83	4400	12	
107	1/16/84	4200	36	
108	2/6/84	5800	24	
4 /24	3/14/83	310		
36	3/21/83	2100		
181	6/13/83	1100		
306	10/10/83	260	1	
426	1/16/84	900	1	
456	2/6/84	900	6	
14 /20	3/14/83	3400		
38	3/21/83	1600		
109	6/13/83	5800		
214	9/12/83	2700	110	
324	1/9/84	2300	61	
NA[1]	4/2/84		41	420
22 /17	3/14/83	3200		
48	4/18/83	3200		
112	8/15/83	900	54	
170	12/5/83	380	6	
196	1/16/84	1300	3	
242	4/2/84		11	190
34 /05	3/7/83	5800		
25	4/18/83	5400		
54	7/11/83	4900		
87	9/12/83	1600	62	
110	11/7/83	610	30	
143	1/16/84	4500	180	
165	3/5/84		20	780
43 /30	2/28/83	1900		
120	4/18/83	2200		
316	7/11/83	3400		
603	11/7/83	3900	5	
709	1/23/84	630	1	
721	3/5/84		27	290
51 /10	2/28/83	720		
32	3/21/83	3200		
130	7/11/83	920		
132	10/10/83	960	2	
146	1/23/84	3300	3	
151	2/6/84	1700	2	
53 /0	2/28/83	710		
11	6/13/83	3900		

[1] NA - not available

SILVERDALE MICROBIOLOGICAL DATA

Standard Plate Count Results (#/ml)

Model F (cont.)

Location /Flow	Date	Unflushed/Un-Disinfected Tap	Flushed/Dis-Infected Tap	1 L Flushed/ Disinfected Tap
53/17	8/15/83	2600	1	
23	11/7/83	1100	2	
33	1/23/84	150	6	
49	3/5/84		5	180
61/20	2/28/83	3300		
125	5/16/83	5800		
186	10/10/83	2700	11	
197	12/5/83	1200	19	
221	1/23/84	340	5	
330	4/2/84		1	6
65/10	2/28/83	2300		
NA[1]	5/16/83	5800		
294	9/12/83	1100	3	
387	12/5/83	900	270	
418	1/23/84	2300	4	
545	4/2/84		1	11

[1]NA - not available

APPENDIX C
VOC AND MICROBIOLOGICAL RESULTS FOR POINT-OF-USE SAMPLES
Rockaway

VOC RESULTS
Pre/Post
Concentration (µg/L)

LOCATION	DATE	TRI-CHLORO-ETHYLENE	TETRA-CHLORO-ETHYLENE	1,1,1-TRI-CHLORO-ETHANE	1,2-DI-CHLORO-ETHANE	CARBON TETRA-CHLORIDE	CHLORO-FORM	BROMODI-CHLORO-METHANE	CHLORO-DIBROMO-METHANE	Bromoform	Methylene Chloride
1											
	10/82	ND/ND	ND/ND	230/ND	--	--	ND/ND	--	--	--	--
	7/83	1/ND	3/ND	154/ND	--	--	1/ND	ND/ND	ND/ND	ND/ND	--
	10/83	ND/ND	ND/ND	82/ND	--	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	--
2											
	10/82	ND/ND	ND/ND	57/ND	--	--	ND/ND	--	--	--	--
	7/83	2/ND	2/ND	10/ND	--	--	2/ND	ND/ND	ND/ND	ND/ND	--
	10/83	ND/ND	ND/ND	20/ND	--	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	--
3											
	10/82	70/ND	ND/ND	ND/ND	--	--	ND/ND	--	--	--	--
	7/83	52/4	1/2	ND/ND	--	--	ND/ND	ND/ND	1/ND	ND/ND	--
	10/83	161/ND	ND/ND	0.8/ND	--	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	--
4											
	10/82	160/ND	ND/ND	ND/ND	--	--	ND/ND	--	--	--	--
	10/83	150/ND	ND/ND	ND/ND	--	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	--
5											
	10/83	ND/ND	ND/ND	12/ND	--	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	--
6											
	10/83	ND/ND	ND/ND	ND/ND	--	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	--
7											
	10/83	-/ND	-/ND	-/ND	--	-/ND	-/ND	-/ND	-/ND	-/ND	--
8											
	10/83	ND/ND	ND/ND	ND/ND	--	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	--
9											
	10/83	ND/ND	ND/ND	ND/ND	--	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	--

ROCKAWAY TOWNSHIP MICROBIOLOGICAL RESULTS
Pre/Post (#/mL)

Location	Date	Unflushed, Undisinfected		Flushed, Disinfected	
		SPC	Coliform	SPC	Coliform
1	7/25/83	<10/>10	<1/<1		
	10/26/83	<10/20	<1/<1	<10/<10	<1/<1
2	7/25/83	<10/<10	<1/<1		
	9/8/83	2,000/32,000	<1/<1	<10/<10	<1/<1
	10/26/83	570/<10	<1/<1	<10/<10	<1/<1
	12/1/83	700/<10	127/<1	<10/<10	<1/<1
3	7/12/83	<10/150	<1/<1		
	9/8/83	250/210	<1/<1	<10/<10	<1/<1
	10/26/83	350/550	<1/<1	<10/<10	<1/<1
	12/1/83	1,800/10	<1/<1	<10/150	<1/<1
4	7/12/83	430/<10	<1/<1		
	10/26/83	<10/350	<1/<1	230/<10	<1/<1
5	9/8/83	<10/540	<1/<1	<10/70	<1/<1
	10/26/83	400/3,600	<1/<1	250/<10	<1/<1
6	9/8/83	40/380	<1/<1	10/120	<1/<1
	10/26/83	2,300/2,700	<1/<1	2,200/1,600	<1/<1
	12/1/83	1,000/130	<1/<1	1,400/60	<1/<1
7	10/26/83	<10/1,100	<1/<1	<10/<10	<1/<1
	12/1/83	200/10	3/<1	60/<10	<1/<1
8	10/26/83	<10/170	<1/<1	<10/<10	<1/<1
9	10/26/83	2,200/3,600	<1/<1	110/<10	<1/<1
	12/1/83	<10/110	<1/<1	<10/<10	<1/<1
10	9/8/83	5,400/1,200	35/<1	<10/1,000	<1/<1

APPENDIX D

MICROBIOLOGICAL RESULTS USING R2A AND SMA MEDIA

A specially developed plate count medium (R2A) was used to enumerate organisms in unflushed postdevice water samples collected in Silverdale, Pennsylvania. Samples were collected daily for one month. Organisms were enumerated using the R2A and standard methods agar (SMA).

The R2A media composition is presented in Table D-1. The significant difference in this media versus SMA is the inclusion of sodium pyruvate, which enhances the recovery of stressed cells. For the oligotroplic environment of groundwater, the use of this media produces a greater potential for enumeration of total heterotrophic organisms.

Table D-2 presents results of bacterial enumeration using both media. Paired samples of effluent from two of the same model non-silvered carbon devices and silvered carbon devices were enumerated.

The differences between media are not as pronounced as the differences between silver and non-silver impregnated carbon. The difference between 48 and 72 hour incubation indicates the presence predominately slow growing organisms in the effluent from the carbon beds.

TABLE D-1. COMPOSITION OF R2A MEDIUM

INGREDIENT	CONCENTRATION, µg/L
Yeast Extract	0.5
Proteose Peptone No. 3	0.5
Casamino Acids	0.5
Glucose	0.5
Soluble Starch	0.5
Sodium Pyruvate	0.3
K_2HPO_4	0.3
$MgSO_4.7H_2O$	0.05
Agar	15.0

Final pH 7.2, adjust with K_2HPO_4 or KH_2PO_4 before adding agar. Add agar, heat medium to boiling to dissolve agar and autoclave for 15 minutes at 121°C, 15 psi.

Table D-2. GAC Postfilter Mean Standard Plate Counts Standard Methods Agar vs R2A Medium

Sample Type	Standard Methods Agar	R2A Medium
48 hr Incubation		
Silver	3556	4572
Non Silver	130	155
Combined	585	720
72 hr Incubation		
Silver	6145	7118
Non Silver	210	267
Combined	990	1190